REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	August 2002	USARIEM TECHNICAL REPORT`

4. TITLE AND SUBTITLE
SIMULATED HUMAN RESPONSES TO TRANSIENT COLD WET SEA EXPOSURE SEQUENCES

5. FUNDING NUMBERS

6. AUTHOR(S)

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Command
Fort Detrick, MD 21702-5007

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

20020816 027

13. ABSTRACT *(Maximum 200 words)*
The risks of hypothermia were estimated by human simulation modeling for a sea rescue scenario in various cold to cool conditions. The Warfighters were assumed to be wearing a battle dress uniform (BDU) or similar clothing. The exposure sequence started from a resting neutral comfortable thermal state. They then entered the outside air conditions for 15 minutes before entering the water. After 15 minutes in the water they climbed on to a wet raft that contained about a foot of seawater sloshing about and remained there for up to 24 hours before being rescued. Simulations of the human responses to these events were made for a 13°C sea temperature with air temperatures (Ta) of 10, 15 and 20 °C and wind velocities (Va) of 5, 10 and 20 km/h. Further simulations where made to estimate the effect if any of physiological fitness and of elevated activity levels before reaching the raft.

The results indicate that in the 13°C water, body heat loss is rapid and at the point of climbing on to the raft the thermal physiological state is fairly independent of activity, physiological fitness and cardiovascular differences. Once on the raft the progression of Warfighters' thermal state depended strongly on the Ta and Va, and their ability to shiver and sustain it. The simulation model estimates reported here compare favorably with core temperature measurement of 20 persons during a 7.5 hour sea and wet raft exposure in 20°C air.

14. SUBJECT TERMS	15. NUMBER OF PAGES
hypothermia, shivering, modeling, cold exposure, sea rescue, core temperature	79
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
U	U	U	U

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USARIEM TECHNICAL REPORT T-02/..

Simulated Human Responses to Transient Cold Wet Sea Exposure Sequences

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AUGUST, 2002

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AQM02-11-2650

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BACKGROUND LIST OF ABBREVIATIONS AND ACRONYMS

α = mass of skin/total body mass

BDU = battle dress uniform

Cdil = proportional skin blood flow control constant in Liters/(h m^2 ΔTmb)

Clo = thermal insulation unit for clothing, 1 clo = 0.159 m^2C/w

Met = metabolism/resting metabolism

Skbf = skin blood flow in Liters/(h m^2)

Skbfmin = minimum skin blood flow in Liters/(h m^2)

Ta = air temperature °C

Tc = body's core temperature °C

Tmb = mean body temperature = αTsk - (1-α)Tc

Tsk = skin temperature °C

Va = wind velocity in km/h

EXECUTIVE SUMMARY

The risks of hypothermia were estimated by human simulation modeling for a sea rescue scenario in various cold to cool conditions. The Warfighters were assumed to be wearing a battle dress uniform (BDU) or similar clothing. The exposure sequence started from a resting neutral comfortable thermal state. They then entered the outside air conditions for 15 minutes before entering the water. After 15 minutes in the water they climbed on to a wet raft that contained about a foot of seawater sloshing about and remained there for up to 24 hours before being rescued. Simulations of the human responses to these events were made for a 13°C sea temperature with air temperatures (Ta) of 10, 15 and 20 °C and wind velocities (Va) of 5, 10 and 20 km/h. Further simulations where made to estimate the effect if any of physiological fitness and of elevated activity levels before reaching the raft.

The simulation assumed the Warfighters were dry before entering the water but that their clothing remained wet in the raft until rescued. The thermal physiological simulation model considered the human to be characterized as three thermal compartments (core, skin and clothing). As used, the model is an adaptation of existing successful models.

The results indicate that in the 13°C water, body heat loss is rapid and at the point of climbing on to the raft the thermal physiological state is fairly independent of activity, physiological fitness and cardiovascular differences.

Once on the raft the progression of Warfighters' thermal state depended strongly on the Ta and Va, and their ability to shiver and sustain it. After 90 minutes on the raft, the Warfighter typically reached a quasi-steady thermal state. For the 20°C condition, hypothermia is small as is the wind effect. At Ta of 15°C, wind is a strong factor but if shivering continues their core temperature, as simulated for 24 hrs, was shown not to go below about 36.5°C even in a 20 km/h wind. The 10°C condition is the most threatening of those simulated and the threat increases with air speed. If shivering is sustained, core temperatures after 90 minutes on raft were predicted to be about 36.4°C in a 5 km/h wind and 36.0°C with a 20 km/h wind. After 24 hours, the latter would be expected to be about 35.95°C. The simulated quasi-steady core temperatures after 90 minutes on raft are:

Ta°C \ Va	5	10	20 km/h
10	36.42	36.20	35.99
15	36.91	36.78	36.66
20	37.00	36.98	36.95

Cardiovascular and physiological fitness differences and the effect of elevated activity in air and water before reaching the raft had negligible effects on the progression of hypothermia as simulated.

The simulation model estimates reported here compare favorably with core temperature measurement of 20 persons during a 7.5 hour sea and wet raft exposure in 20°C air. However, this model and any model is generally considerably less sophisticated than the human it represents. The results in this report are prepared as a simple useful guide and aid for measurement and rescue planning during various operations/training scenarios.

INTRODUCTION

The quantification of health risks and their minimization for unusual thermal environments and situations can often be facilitated by human response simulation techniques. That is the basis of this report, which in this case is to assess the risk and extent of hypothermia during sea accidents and rescues in cold non-freezing weather or similar situations.

The scenario of events is of a person in ordinary clothing (long sleeved shirt and trousers) falling or entering the water and maneuvering to a raft. The person climbs on to the raft and waits for rescue. The raft may contain water with a depth of about 20cm and so from the wind, waves and raft water it can be assumed that the person's clothing would likely remain soaking wet during the wait. The judgment of risk for hypothermia in this case is assisted by time dependent predictions of body temperatures, skin blood flows and levels of shivering generated by a human thermal response simulation model. For the particular simulation an existing reliable thermo physiological model was adapted for the specific circumstances. Specifically, adaptations where made for water immersion and for heat loss in air from water soaked clothing.

Thermoregulatory models have been evolving for many years. The model used here (Gagge,1986) is a simplification of more complicated models developed by Stolwijk and Hardy (1966, 1970). The model was chosen for its simplicity and practicality even though it was developed for neutral to hot environments. The model does not have appendages, hands, fingers etc and as such oversimplifies blood flow regulation to extremities and body thermal uniformity. Models with appendages (Stolwijk, 1970) and further perfected for cold water situations (Montgomerery, 1972) could improve vascular response prediction but also would introduce complexities and other difficulties that were judged undesirable and not expedient for this exploratory effort.

METHODS

BIOPHYSICAL MODEL

The model (Gagge, 1986) adapted has two active thermal physiological compartments representing core and skin and a passive clothing compartment. In this scheme all of the metabolic heat is generated in the core compartment. Except for the energy lost by breathing and any external thermodynamic work done by the muscles, all of the remaining heat flows to the skin and or is stored in the core. For simplicity, thermodynamic work (raising a weight, rowing etc) was neglected in this simulation. The temperature of the core is automatically maintained within narrow limits by regulating blood flow to the skin and by initiating and modulating shivering. For this, the function for shivering of the Gagge model was replaced with the shivering function formulated by Tikusis (1999). Both shivering and skin blood flow regulators were modeled as acting in proportion to deviations in body temperatures. All other heat transfer processes of the core are passive. The skin in turn transfers the heat to the environment by radiation, convection and evaporation. The secretion of sweat for evaporation is the skin's only physiologically controlled (proportional) heat transfer mechanism.

A representation of the simulation model is illustrated in Figure 1. When the clothing is not water soaked the evaporation of sweat is assumed to take place on the skin. The fraction of the skin covered with water necessary to accomplish the evaporation is called skin wettedness (*w*). In the water the evaporation of sweat, if any, is prevented, radiant heat loss is eliminated, the insulation value of the clothing is reduced by a factor of 70 (Gonzalez, 1988), and the conduction/convection coefficient for heat loss from the clothing is increased to 230 $W \cdot m^{-2} \cdot {}^{\circ}C^{-1}$ (Gonzalez, 1988). On the raft the clothing is assume to remain water soaked with the same insulation value as it had in the water. The water in the clothing is modeled to evaporate from 100 % of the clothing's surface and clothing's water content is considered maintained by wicking and splashing. Radiation and convection are assumed equivalent to values described for normal clothing. The thermal capacity of the clothing is neglected throughout, thus clothing temperature changes instantly to maintain a neutral energy balance on the clothing. In reality, clothing weight would dampen the speed of temperature change but have no effect on steady-state results. A listing of the computer program used is found in Appendix B. An executable program disc is available by writing to USARIEM, EMB.

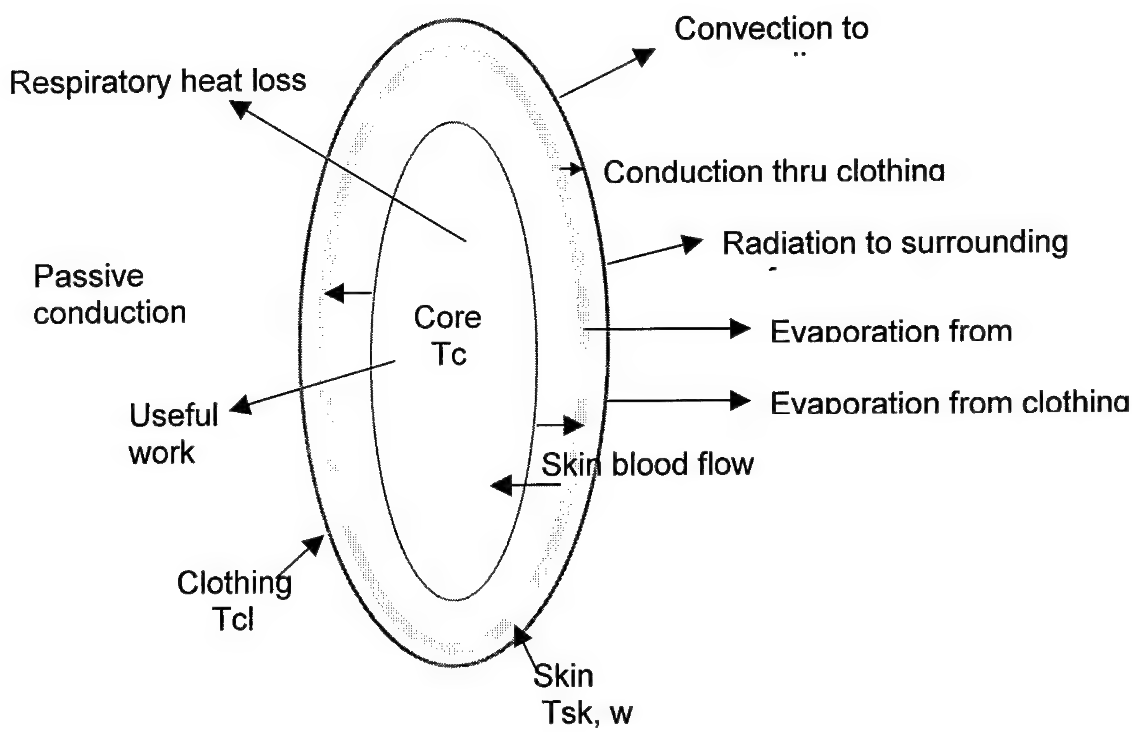

Figure 1. Schematic representation of the two compartment active thermo-physiological model inside of a passive clothing compartment.

SIMULATION CONDITIONS

Thermal responses of humans of average physical fitness who are not strongly cold adapted were simulated for air temperatures of 10, 15 and 20°C with wind speeds of 5, 10 and 20 km/h at each temperature. The effects of fitness and cardiovascular cold adaptation at the coldest and warmest conditions are presented in a following section.

The humans were simulated with a resting (1 met) activity level throughout. The met is a relative metabolism term (met=actual metabolism/resting metabolism). It is seen that shivering can double or triple the resting metabolism. Another following section gives the results for elevated activity levels prior to reaching the raft. The sea temperature was constant at 13°C. The humidity in the air at sea level was assumed to be in equilibrium with the sea surface. That is, the air's dew point temperature (Tdp) equaled sea temperature. In the 10°C air case, the air was assumed to be saturated (Tdp=10°C).

The simulated persons were wearing long sleeved shirts and trousers (intrinsic insulation =0.7 Clo) similar to a battle dress uniform (BDU). At the start of the simulation they were resting with a comfortable thermal physiological state. They entered the outside air conditions and remained there for 15 minutes (0.25h) and then entered the water. They remained in the water for another 15 minutes (0.25h) before climbing on to the raft. They then rested on the raft in a soaking wet state for 23.5 hours.

RESULTS

The time response of core (Tc), average skin temperature (Tsk), skin blood flow (Skbf, $L \cdot m^{2} \cdot h^{-1}$) and net metabolism are presented for the 10, 15 and 20 °C air temperatures conditions in figures 2-4. these Figures show the effect of win in otherwise constant temperature conditions. Each of these figures shows the effect of a temperature exposure at 5 10 and 20 km/h the wind speeds. Figures 5-8 show the effect of air temperature at constant wind speeds. Each figure number has four parts: a) b) c) and d) to show Tc, Tsk, Skbf and Net Met in more detail.

WIND EFFECTS AT CONSTANT TEMPERATURE CONDITIONS

10°C Air Temperature

Figure 2 shows the results for the coldest or 10°C conditions. In part 2a) it is seen that the effect on skin temperature is severe but both core and skin temperatures reach quasi-steady values at about 90 minutes. Increased wind speed results in lower and lower core temperatures that are more clearly shown in Figures 2b and c. It is seen in Figure 2c that Tc decreases about 0.2C with each doubling of the wind speed. Skin temperature decreases about 1°C with wind speed doubling (Figure 2a and d).

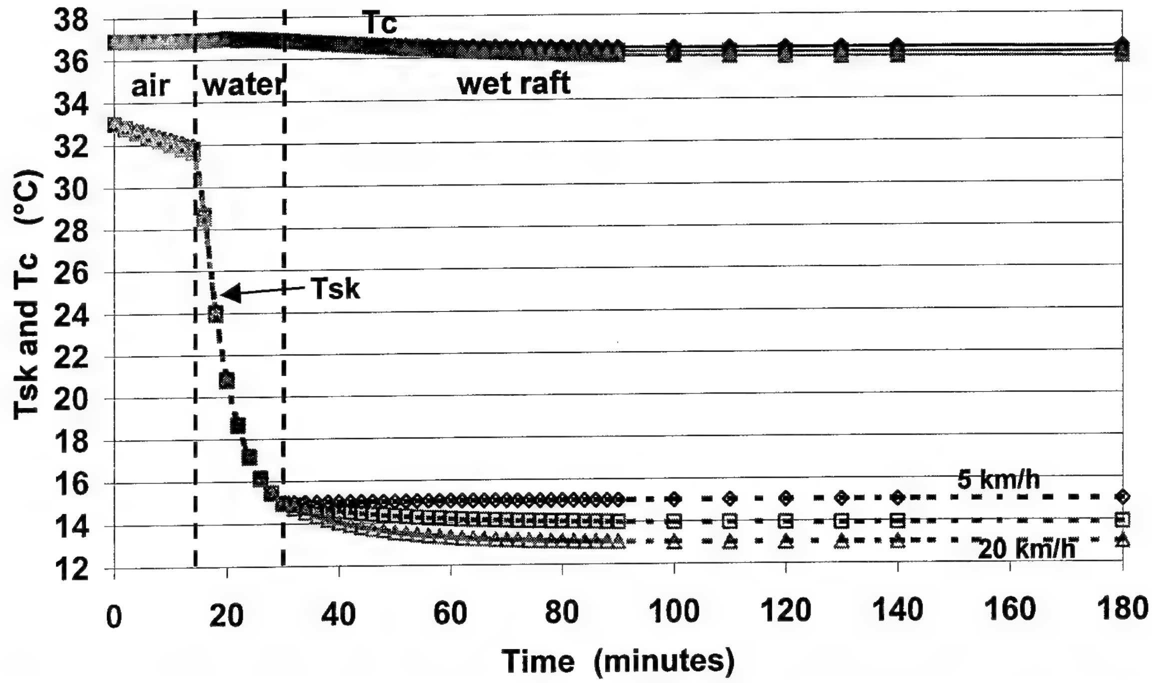

Figure 2a. Wind effect on core and average skin temperatures for air, water, wet raft exposure sequence in 10°C air with 13°C sea at 1 met wearing a BDU.

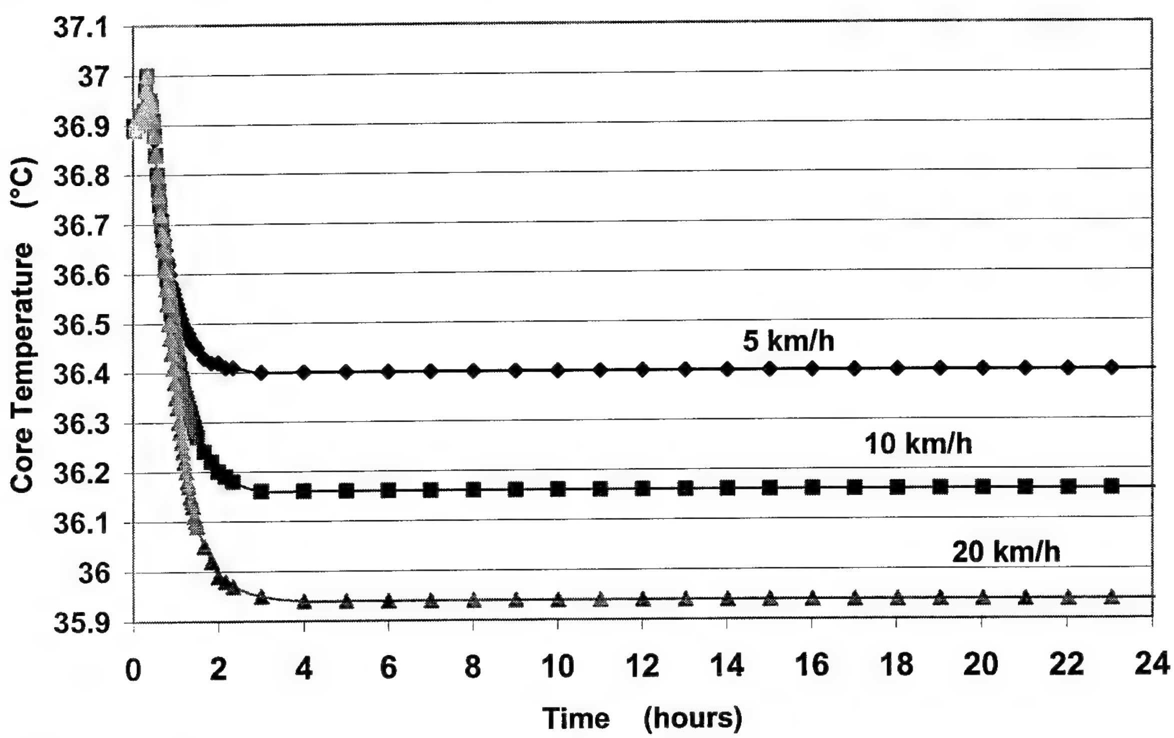

Figure 2b. Wind effect on core temperature (Tc) over 24 hr period in 10°C air with 13°C sea water temperature, 1 met activity level wearing BDU.

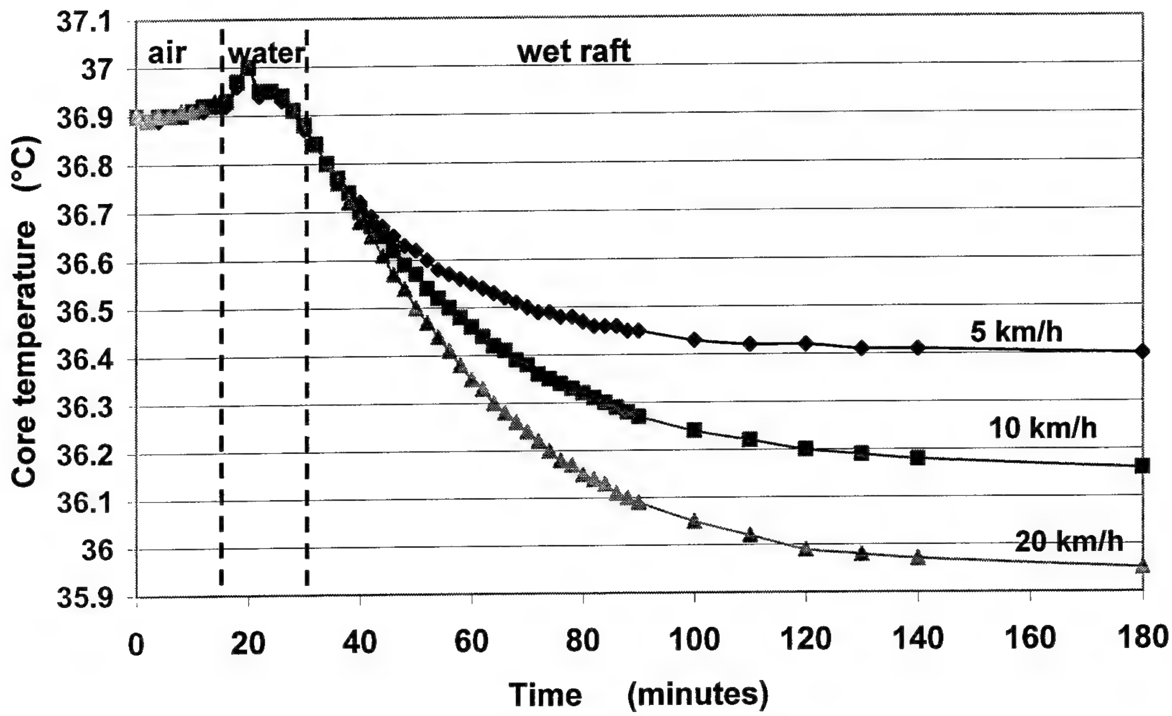

Figure 2c. Wind effect on initial core temperatures in air, water and wet raft exposure with 10°C air, 13°C water conditions.

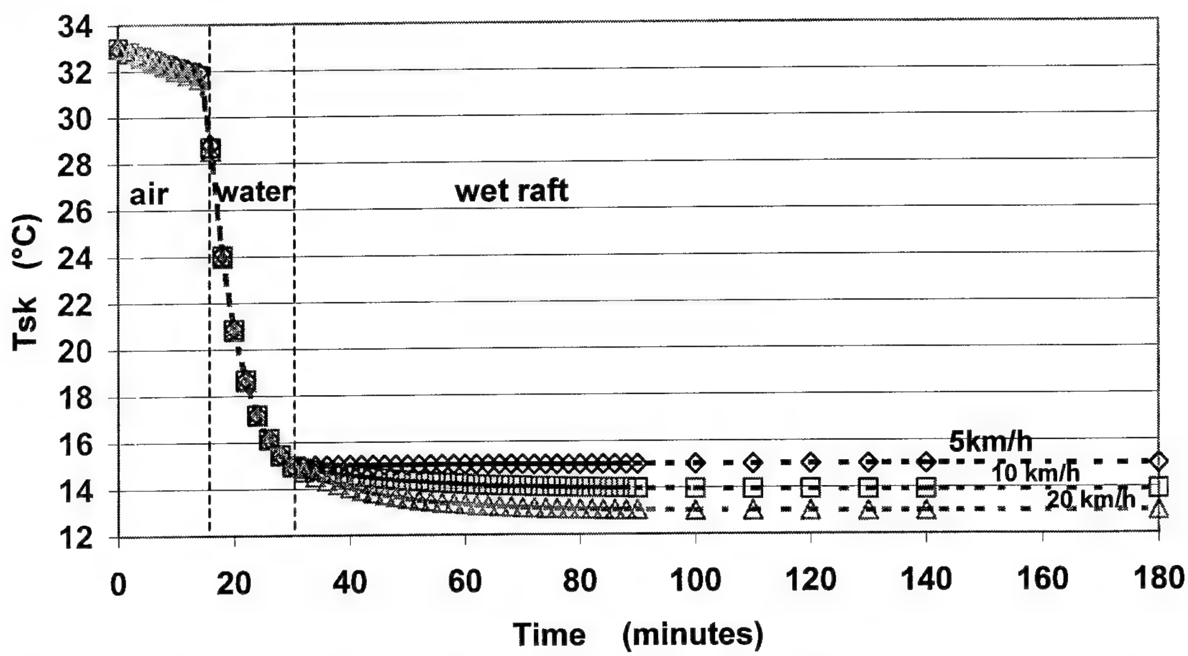

Figure 2d. Wind effect on $\overline{T}_{sk}$ in air water wet raft sequence with 10°C air and 13°C sea at 1 met activity level in BDU.

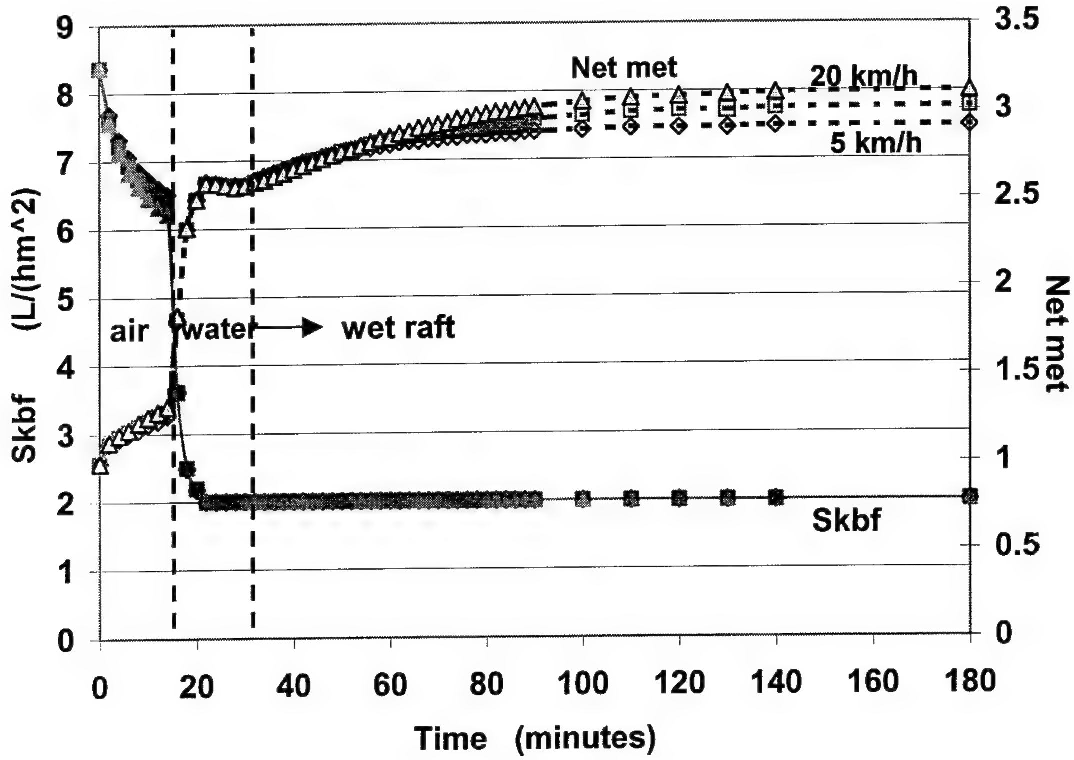

Figure 2e. Wind effect on skin blood flow (Skbf) and metabolism (Net met) for air water, wet raft series in 10°C air with 13°C sea at 1 met activity level with the BDU.

Blood flow to the skin is maximally vasoconstricted at 10°C and 5 km/h winds and cannot be decreased further by increased wind speed (Figure 2e). Wind increases shivering at 10°C. Detailed values of the simulation for these and other conditions are in the output section after the program listing in Appendix B.

15°C Air Temperature

The responses to the 15°C air temperature conditions and accompanying winds are similarly presented in Figure 3. After climbing on to the raft skin temperatures are low but they warm some (Figures 3a & d) in contrast to the 10°C responses where skin temperatures decreased on the raft. Core temperatures on the raft increase slightly from their levels in the water for winds less than 10 km/h. For 20 km/h winds the core temperature deceases slightly further on the raft (Figure 3 a, b and c). Skin blood flow and Net Met (net Metabolic Heat Flux) are unaffected by different wind speeds in the 15°C air conditions) Figure 3e).

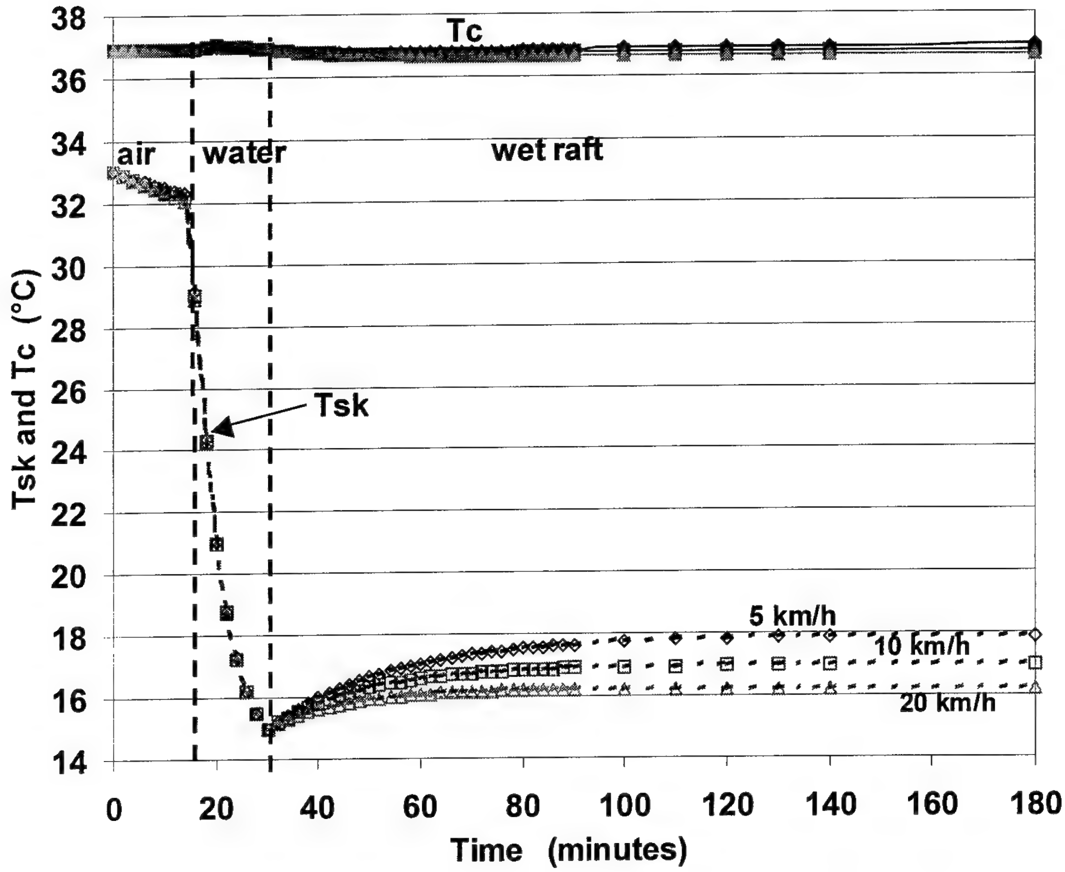

Figure 3a. Wind effect on core and average skin temperatures for air, water, wet raft exposure sequence in 15°C air with 13°C sea temperatures at 1 met activity level in BDU.

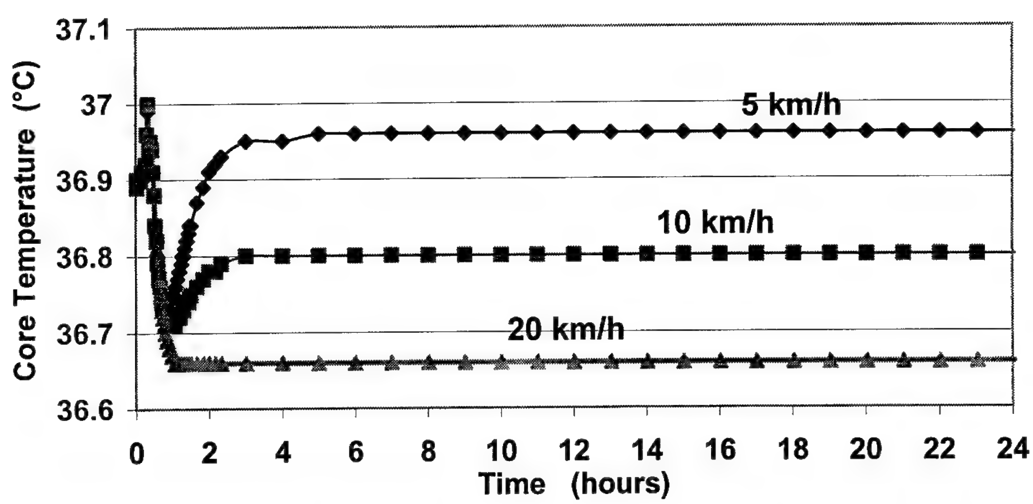

Figure 3b. Effect of wind on Tc over 24 hour period in 15°C air with 13°C sea water temperatures with 1 met activity level wearing BDU.

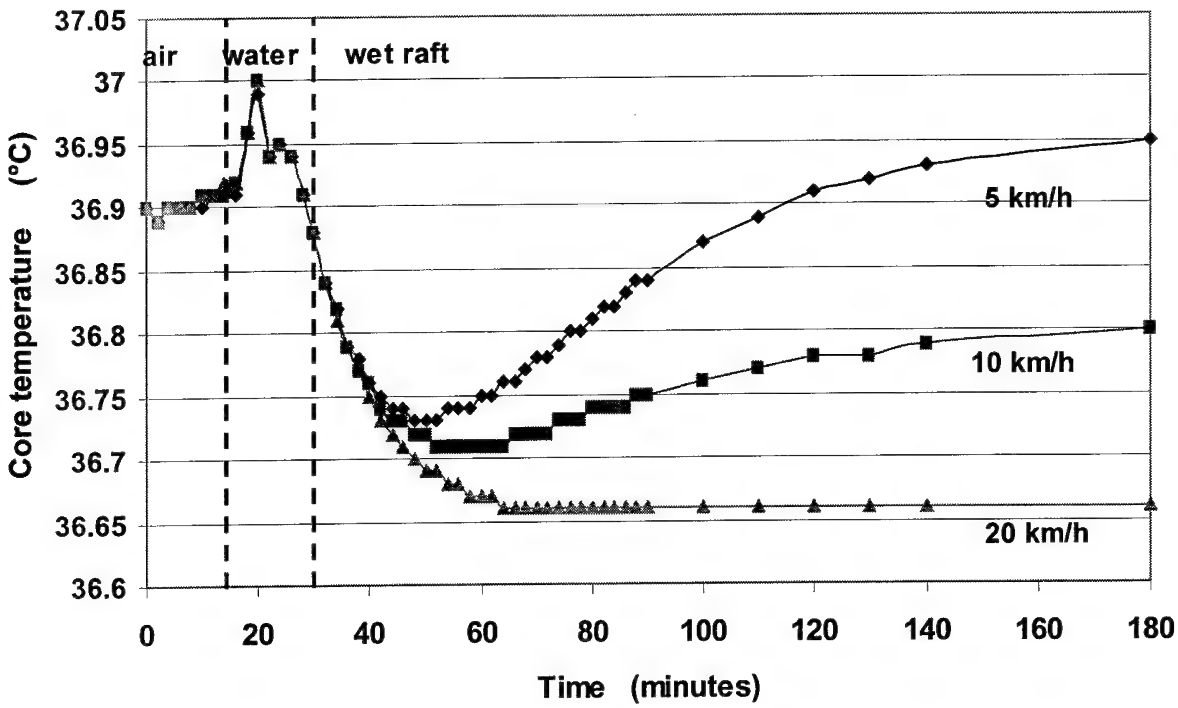

Figure 3c. Wind effect on initial core temperatures in air, water and wet raft exposure with 15°C air and 13°C water conditions.

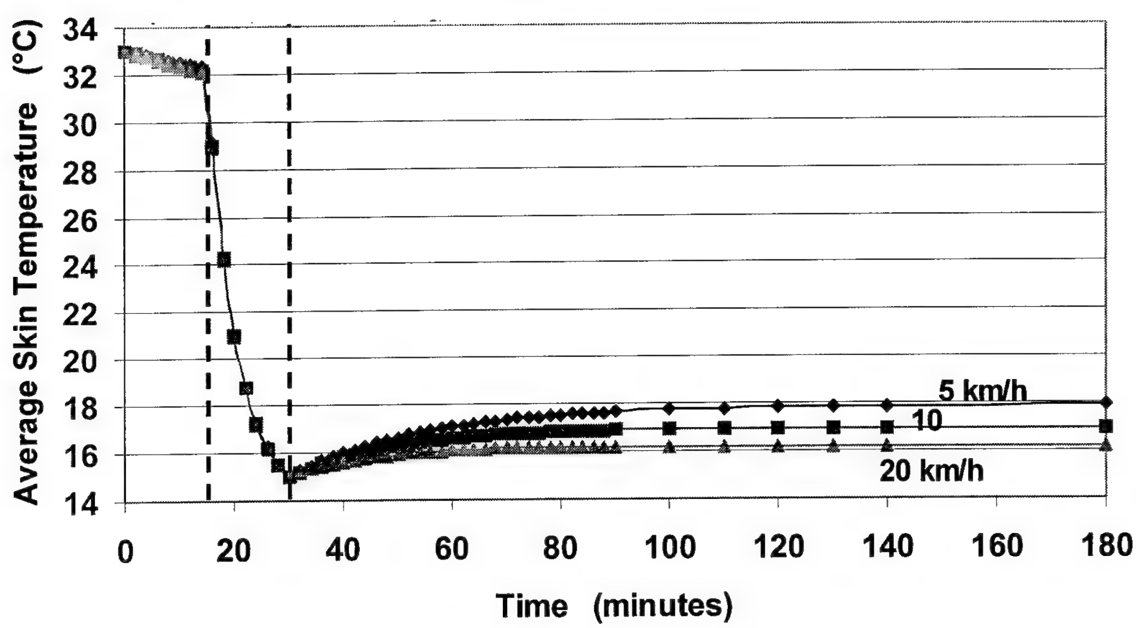

Figure 3d. Wind effect on average skin temperature ($\overline{T}_{sk}$) in air, water and wet raft sequence with 15°C and 13°C sea at 1 met activity level wearing BDU.

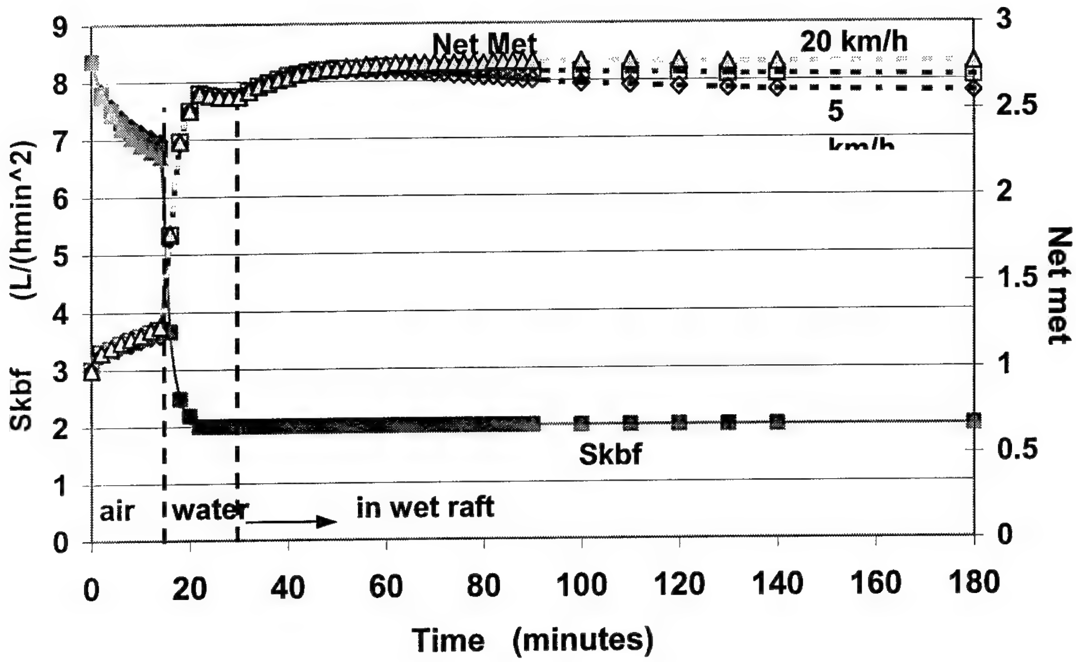

Figure 3e. Wind effect on skin blood flow and metabolism for air water, wet raft series in 15°C air with 13°C sea at 1 met activity level in BDU.

<u>**20°C Air Temperature**</u>

The responses to the 20°C air temperature conditions and winds are similarly presented in Figure 4. After climbing on to the raft, skin temperatures rise 3-5°C above what they were in the water (Figures 4a and d). Core temperatures on the raft basically increase and return to near starting levels (Figures a, b and c) for all wind speeds. Skin blood flow and Net Met are unaffected by different wind speeds in the 20C air conditions (Figure 4e).

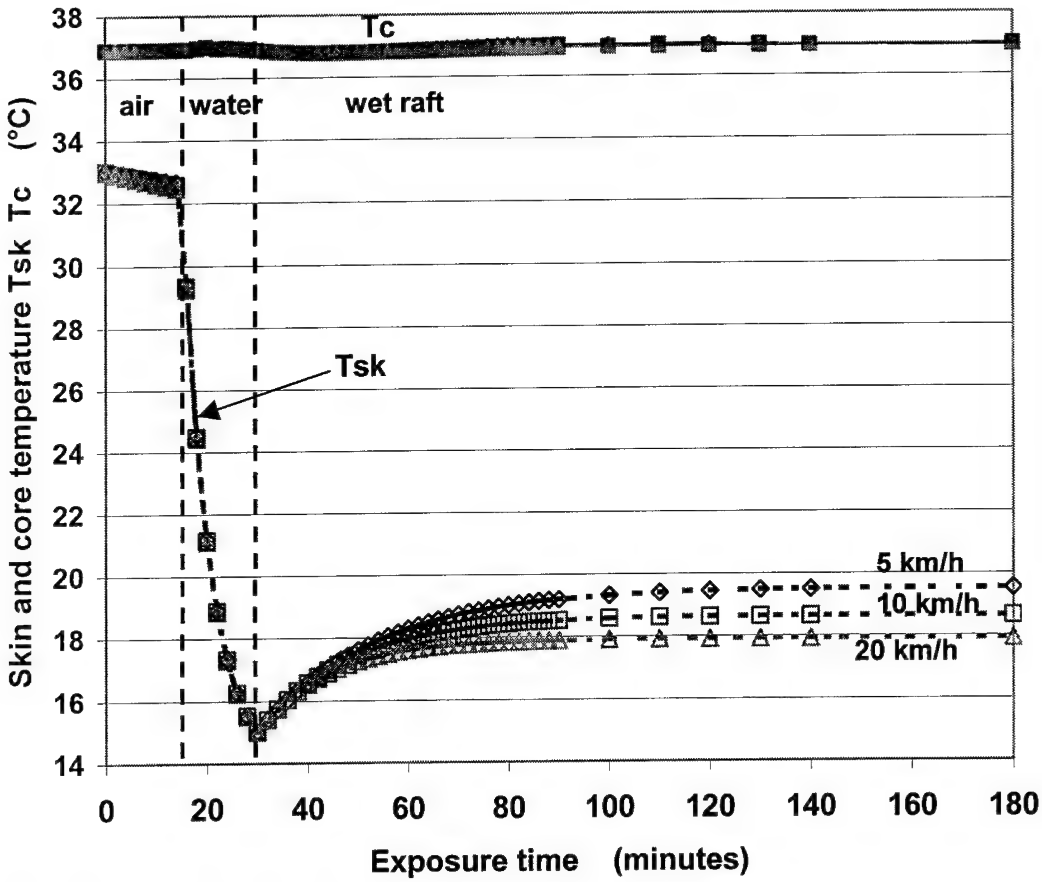

Figure 4a. Wind effect on core and average skin temperatures for air, water, wet raft exposure sequence in 20°C air with 13°C sea at 1 met activity level in BDU.

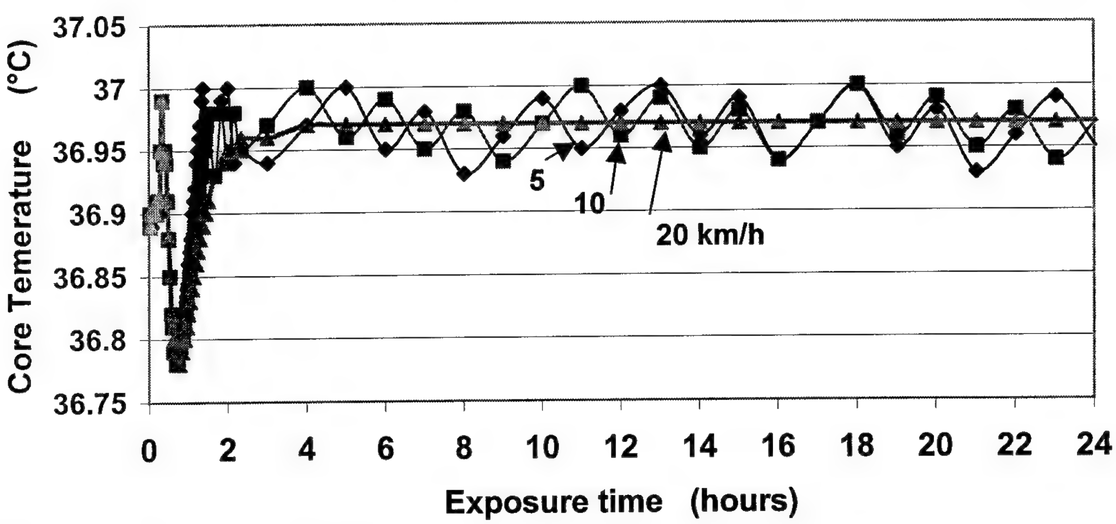

Figure 4b. Wind effect on core temperatures (Tc) in 20°C air and 13°C sea water temperatures with 1 met activity wearing BDU.

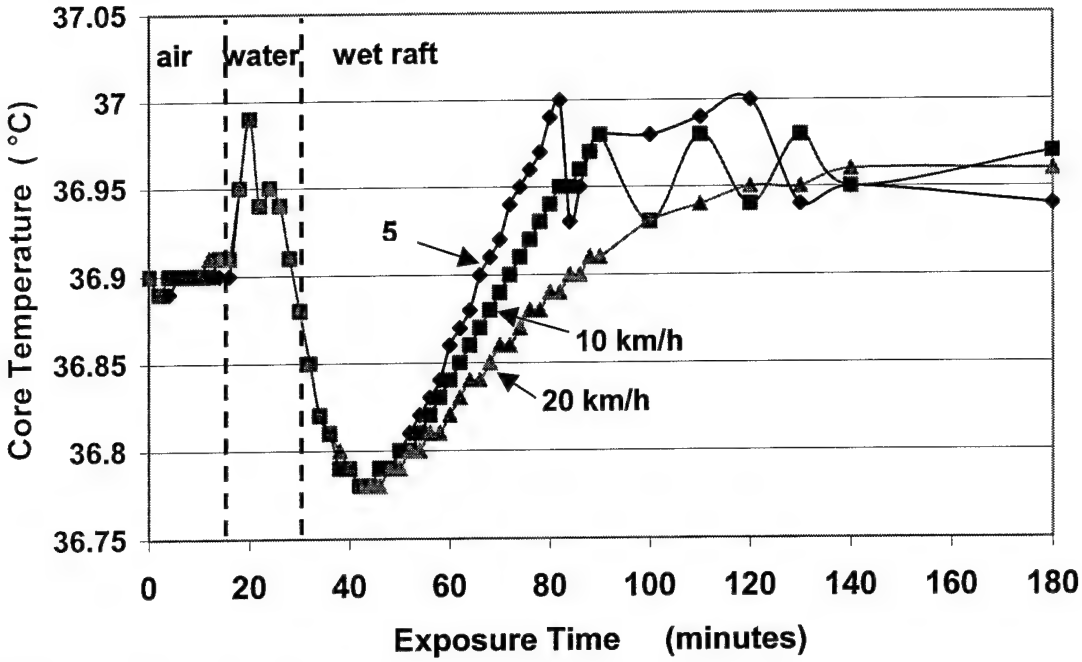

Figure 4c. Wind effect on initial core temperatures in air, water and wet raft exposure with 20°C air, 13°C water conditions.

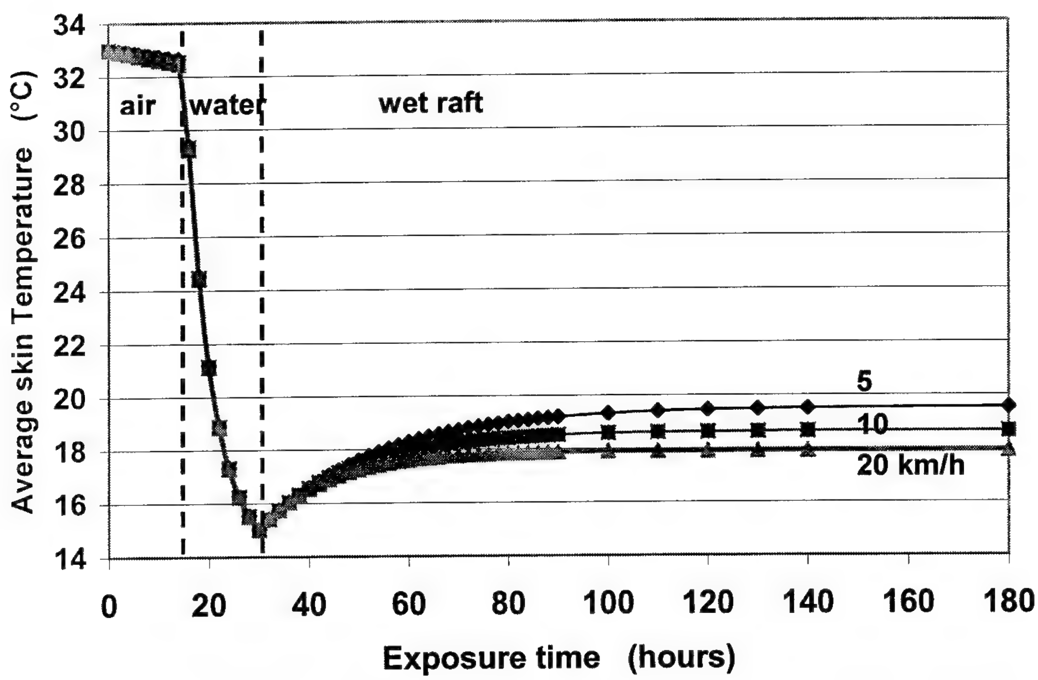

Figure 4d. Wind effect on average skin temperature in air, water and wet raft exposure with 20°C air, 13°C water conditions.

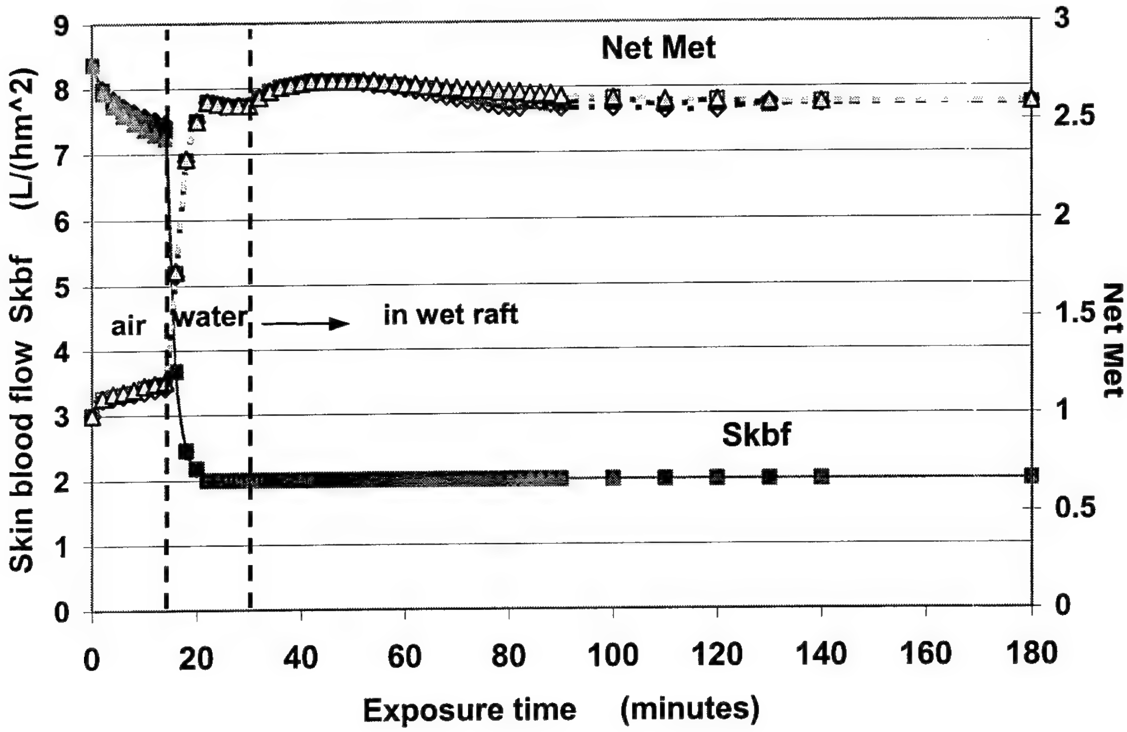

Figure 4e. Wind effect on skin blood flow and metabolism for air, water, wet raft series in 20°C air with 13°C sea at 1 met activity level in BDU.

AIR TEMPERATURE EFFECTS AT CONSTANT WIND SPEEDS

Figures 5-8 show the effect of air temperature at constant wind speeds. Each figure number has four parts: a) b) c) and d) to show Tc, Tsk, Skbf and Net Met in more detail.

5 km/h Wind

At 5km/h wind conditions only the 10°C air temperature has a significant potential for hypothermia (Figure 5) though in all temperatures the skin temperatures will be low and contribute to cold discomfort.

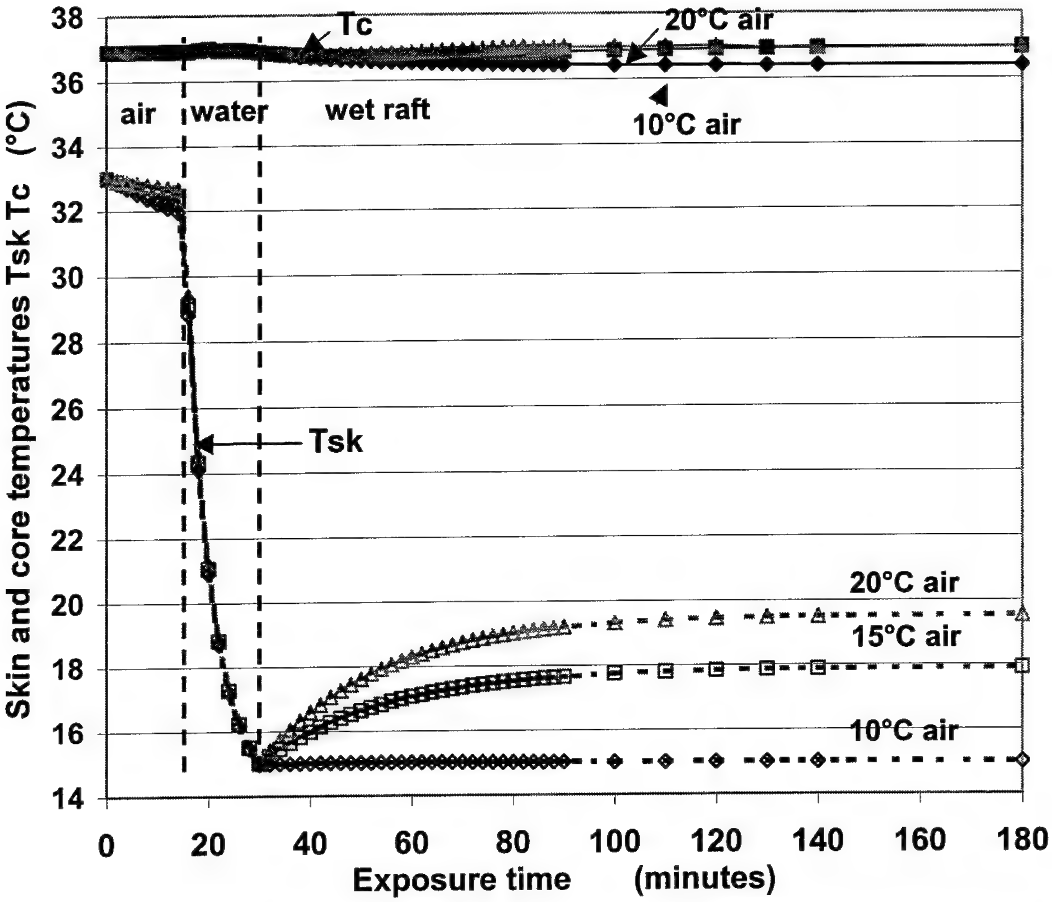

Figure 5a. Temperature effect on core and average skin temperatures for air, water, wet raft exposure sequence in 5 km/h winds with 13°C sea at 1 met activity level with the BDU.

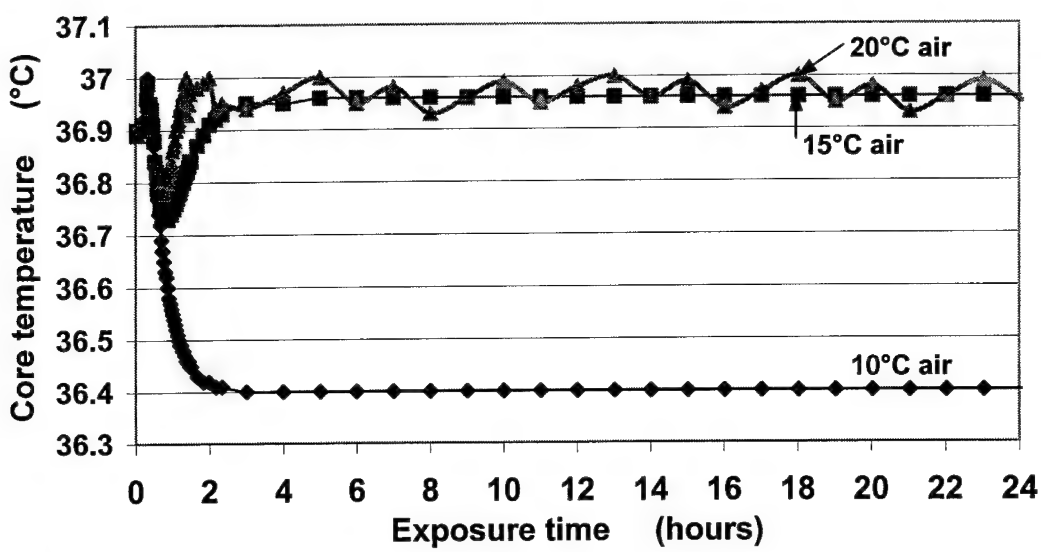

Figure 5b. Air temperature effects on Tc over 24 hour period in 5 km/h wind with 13°C sea water temperature and 1 met activity with the BDU.

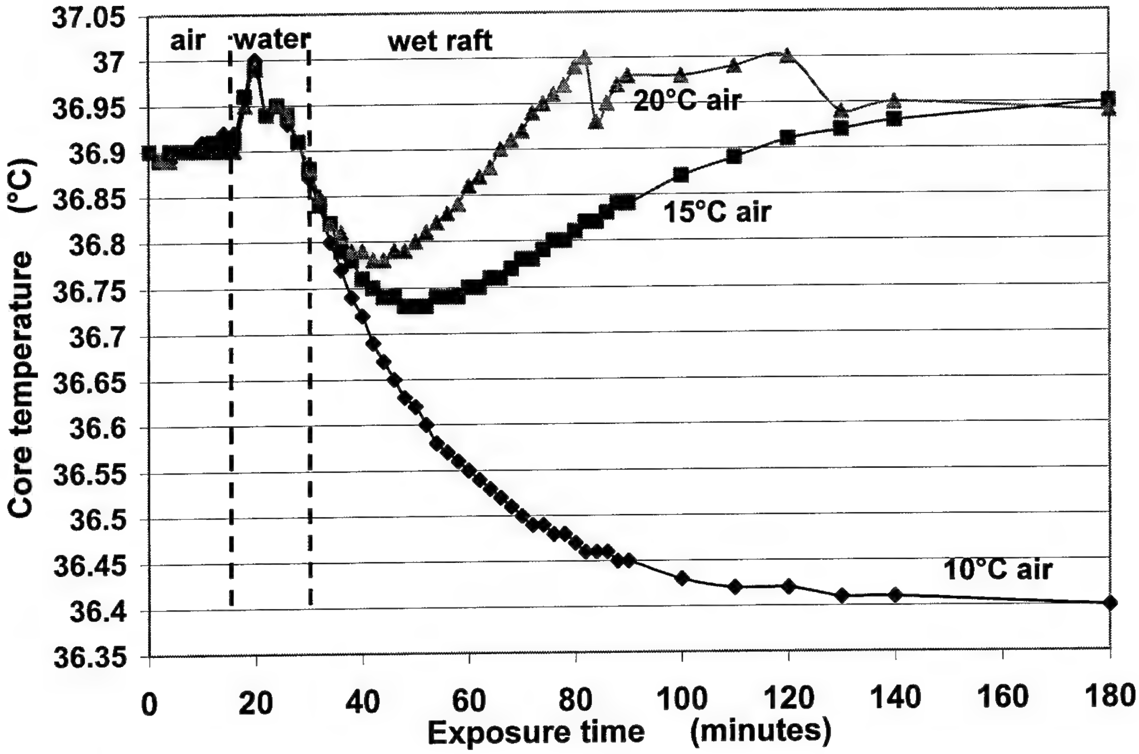

Figure 5c. Temperature effects on Tc in air, water and wet raft exposure with 5km/h wind and 13°C water conditions.

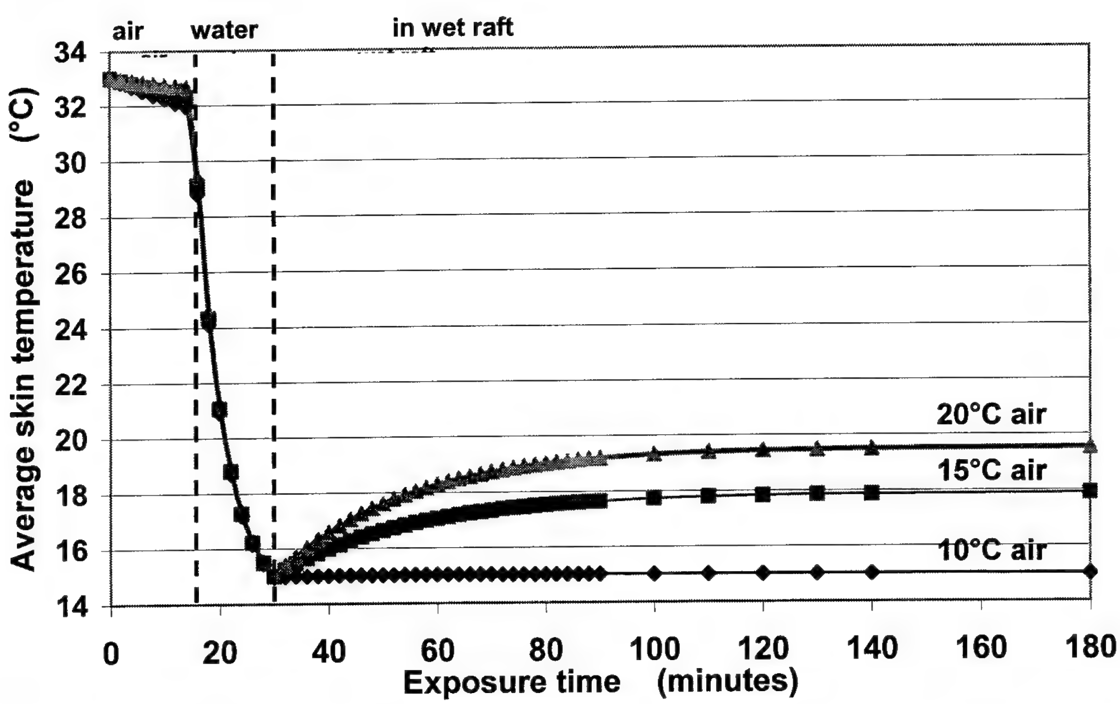

Figure 5d. Air temperature effects on Tsk at 1 met wearing BDU in air, water and wet raft exposure sequence with 5km/h wind and 13°C water conditions.

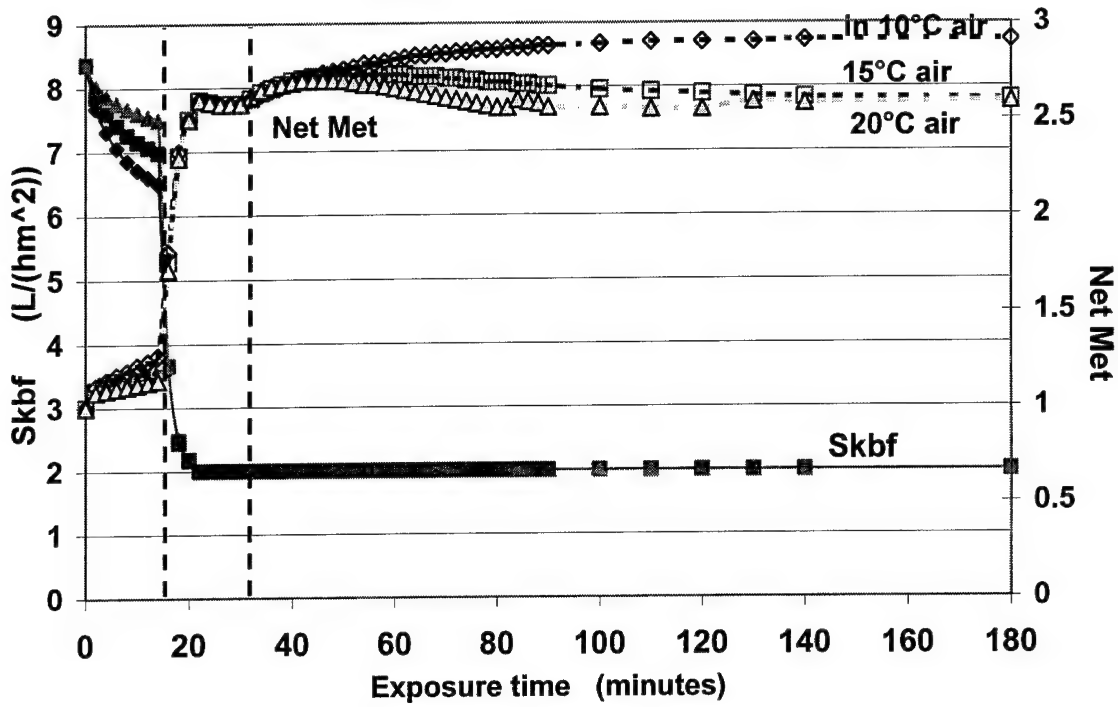

Figure 5e. Temperature effect on skin blood flow and metabolism for air, water, wet-raft series in 5 km/h wind with 13°C sea water temperature at 1 met activity level wearing BDU.

10 km/h Wind

At 10 km/h, only the 20°C air temperature results in near normal core temperatures while waiting on the raft (Figure 6a,b, c and d). Metabolic heat decreases with increasing air temperature (Figure 6e).

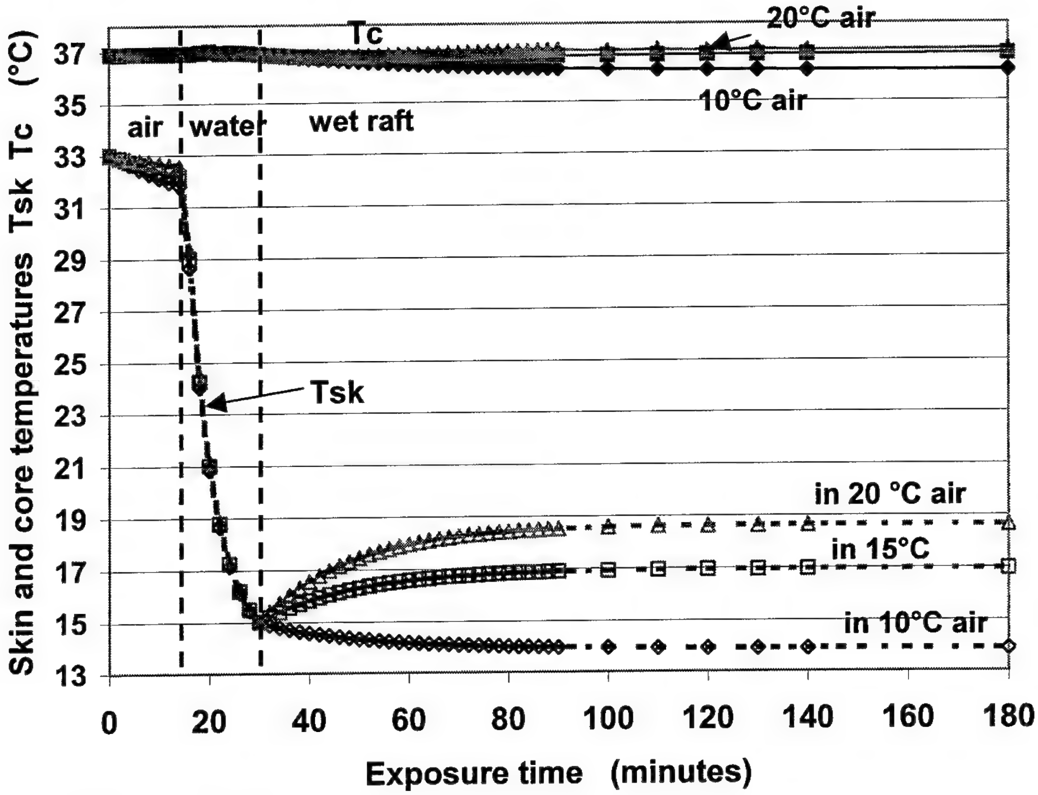

Figure 6a. Temperature effect on core and average skin temperatures for air, water, wet raft exposure sequence in 10 km/h winds with 13°C sea at 1 met activity level wearing BDU.

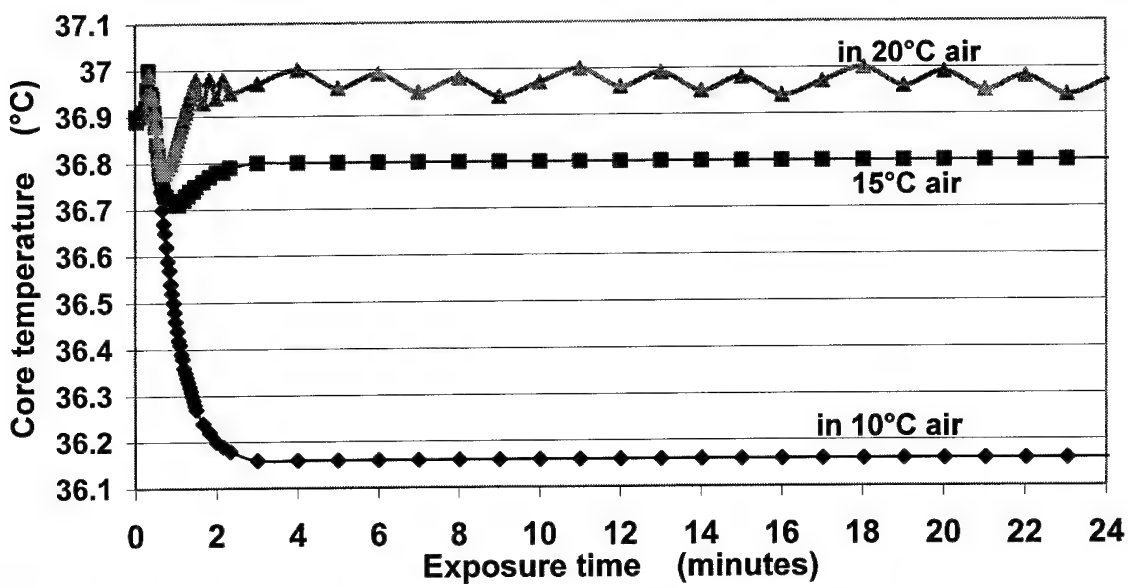

Figure 6b. Air temperature effects on Tc over 24 hour period in 10 km/h wind with 13°C sea and 1 met activity level in BDU.

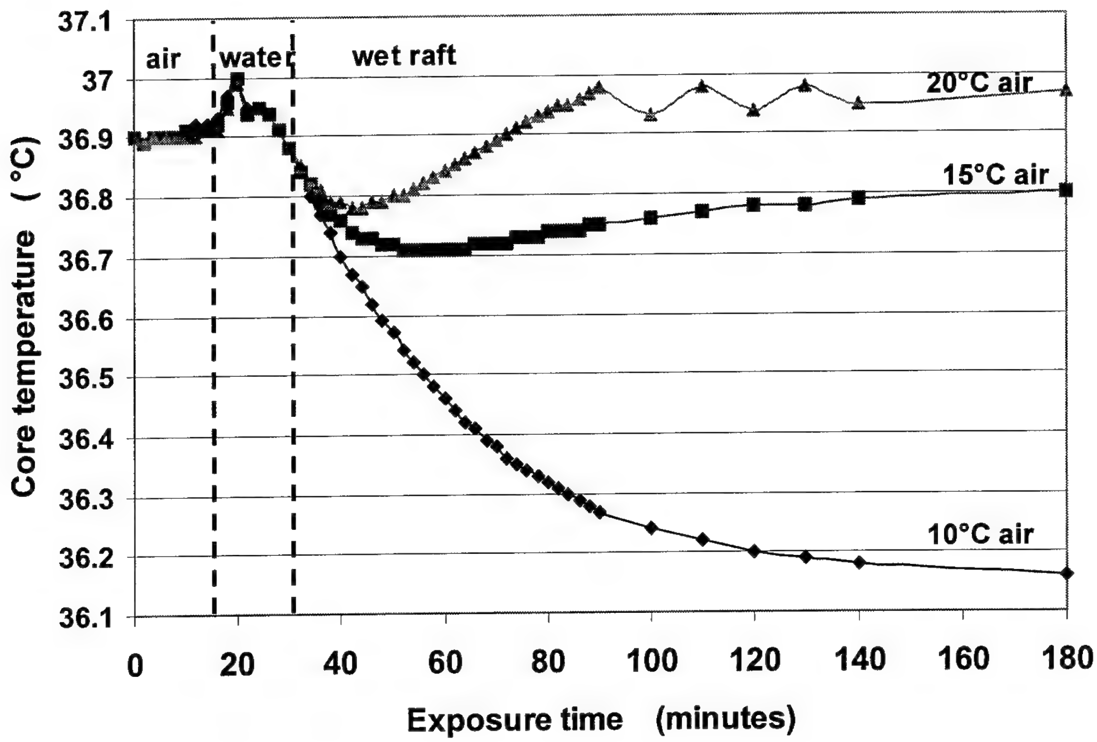

Figure 6c. Air temperature effects on initial core temperatures in air, water and wet raft exposure with 10 km/h wind and 13°C water conditions.

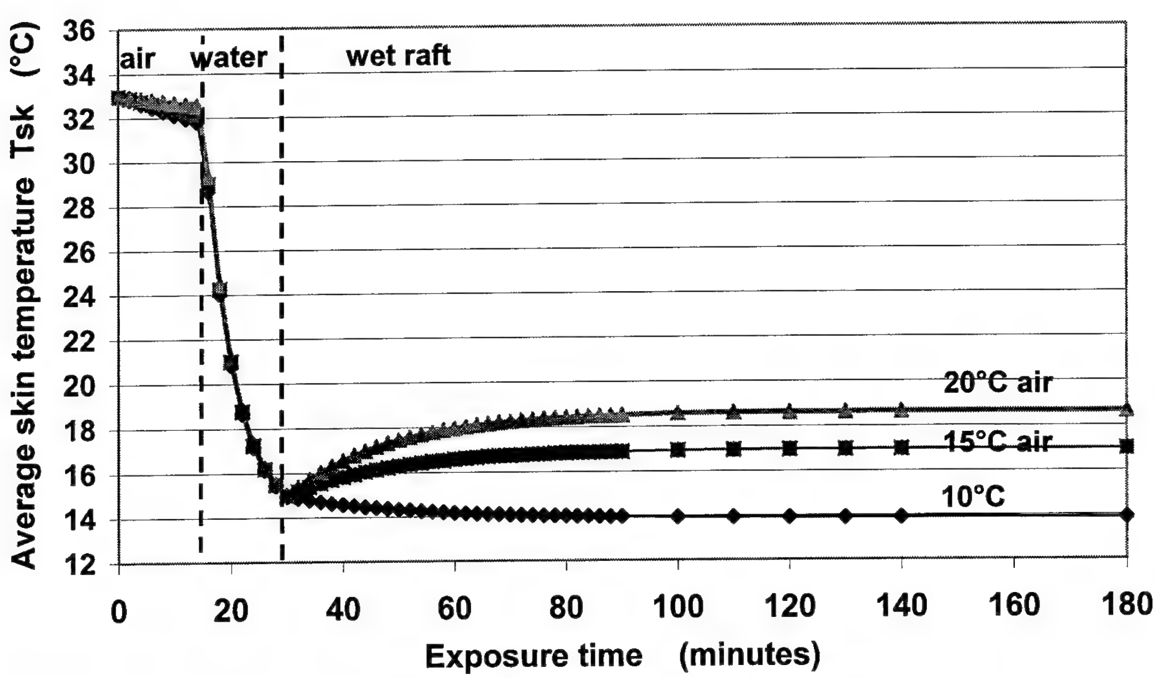

Figure 6d. Air temperature effects on average skin temperature in air, water and wet raft exposure with 10 km/h wind and 13°C water conditions.

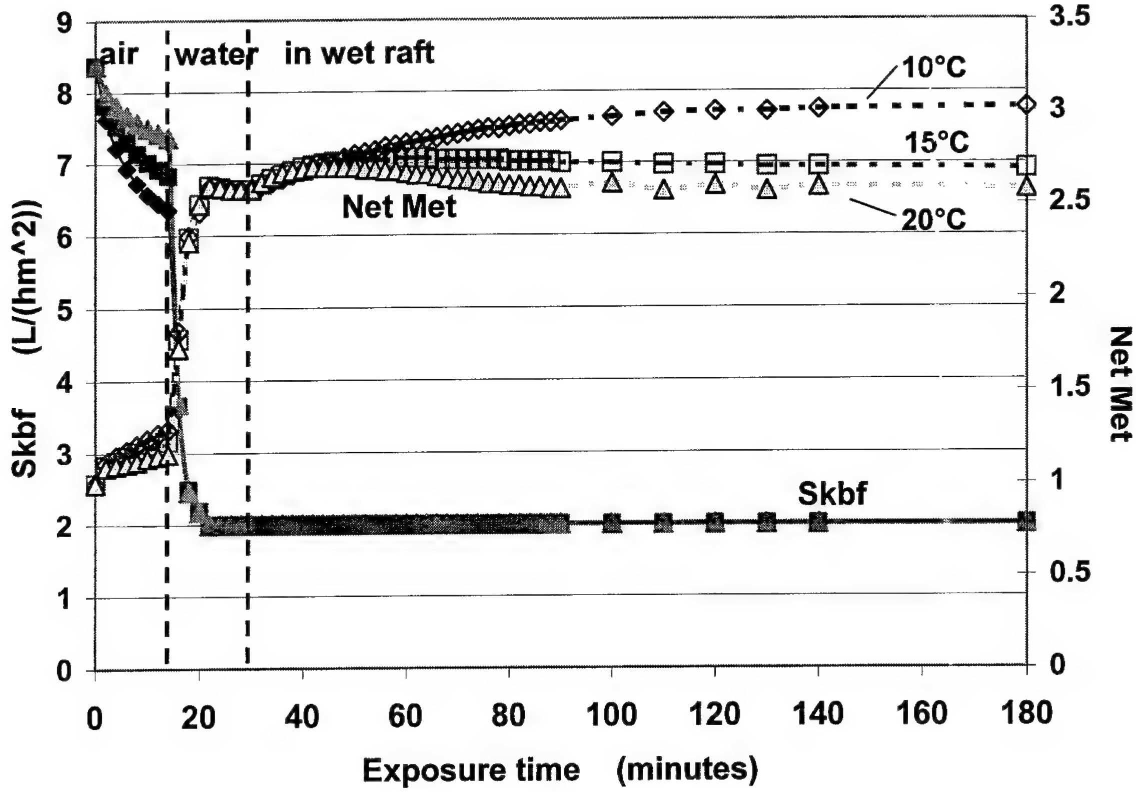

Figure 6e. Air temperature effect on skin blood flow and metabolism for air water, wet raft series in 10 km/h wind with 13°C sea at 1 met activity level wearing BDU.

20 km/h Wind

At 20 km/h, only the 20°C air temperature results in near normal core temperatures while waiting on the raft (Figure 7a,b, c and d). Metabolic heat decreases with increasing air temperature (Figure 7e).

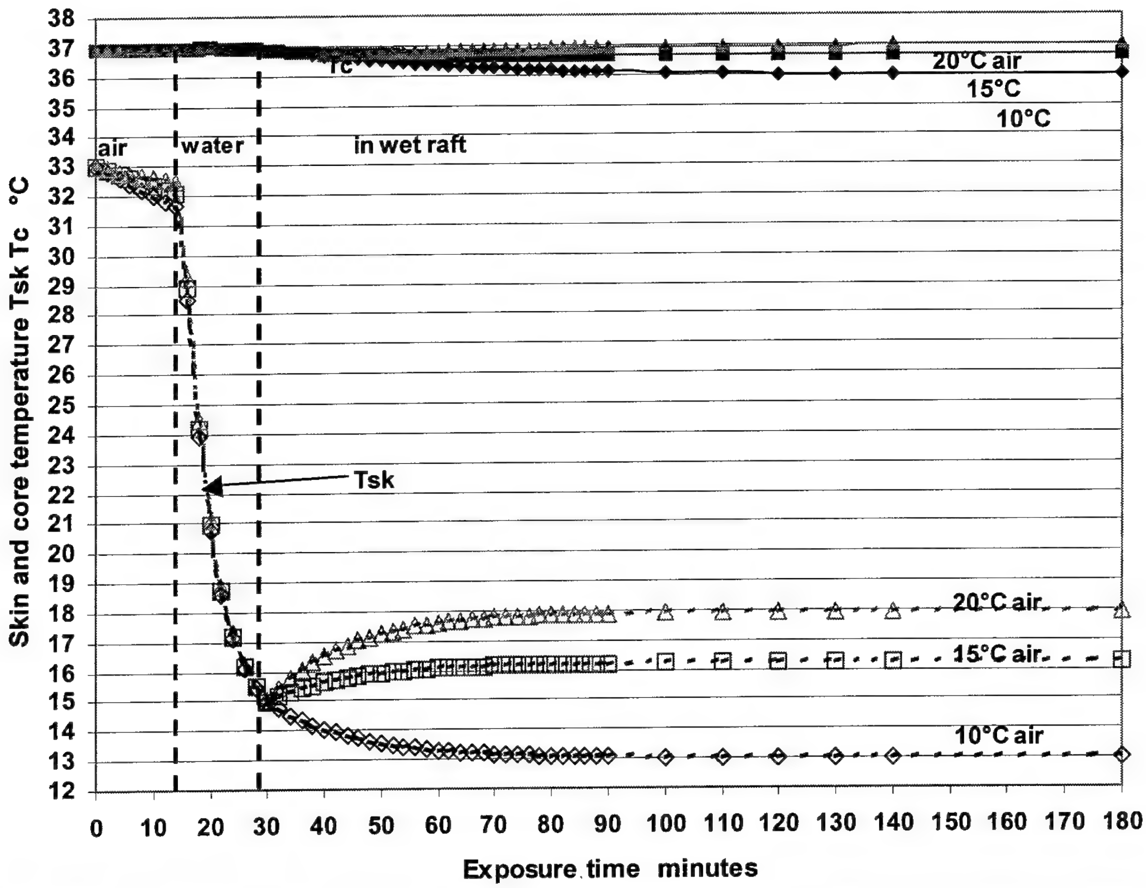

Figure 7a. Temperature effect on core and average skin temperatures for air, water, wet raft exposure sequence in 20 km/h winds with 13°C sea at 1 met activity level wearing BDU.

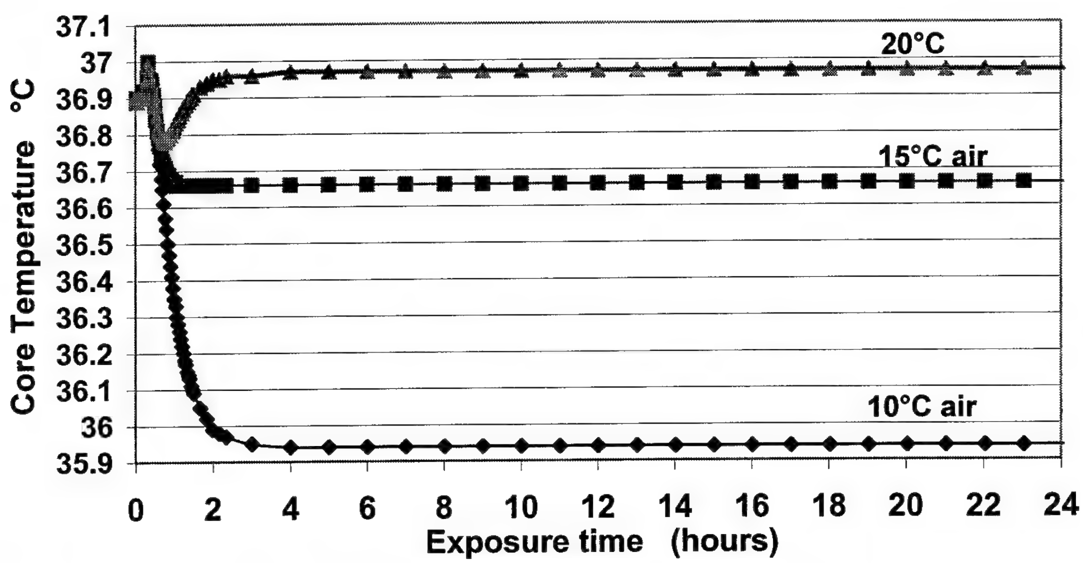

Figure 7b. Air temperature effects on Tc over 24 hour period in 20 km/h wind with 13°C sea water temperature and 1 met activity wearing BDU.

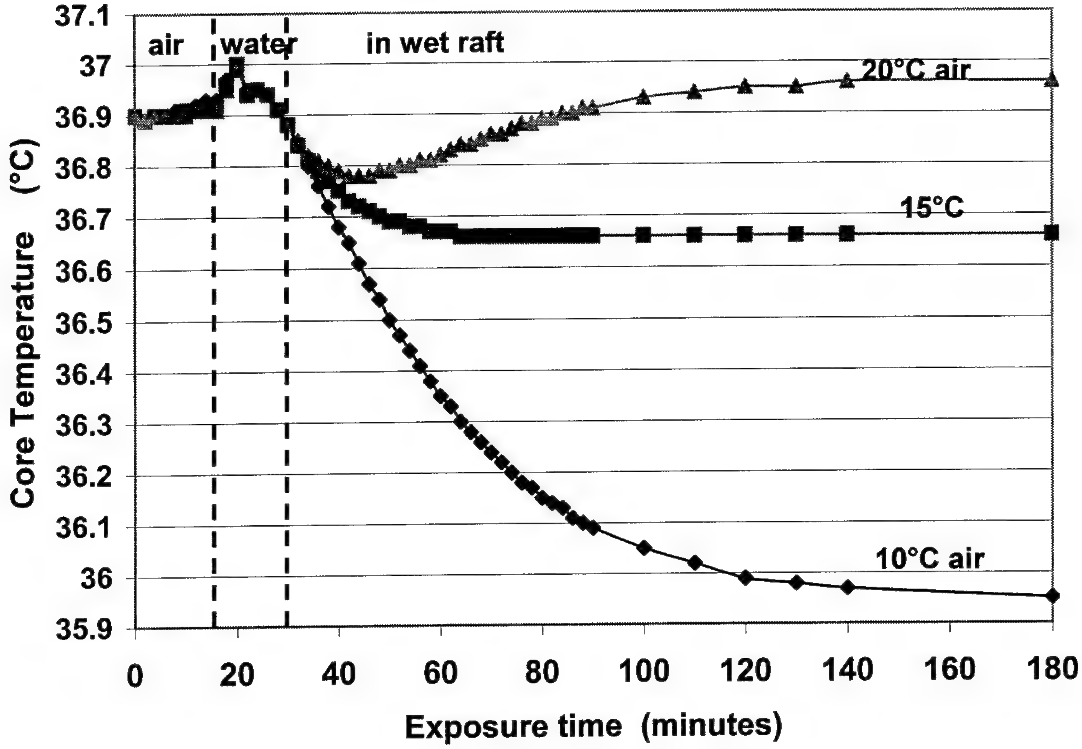

Figure 7c. Air temperature effect on Tc in air, water and wet raft exposure with 20 km/h wind and 13°C water conditions.

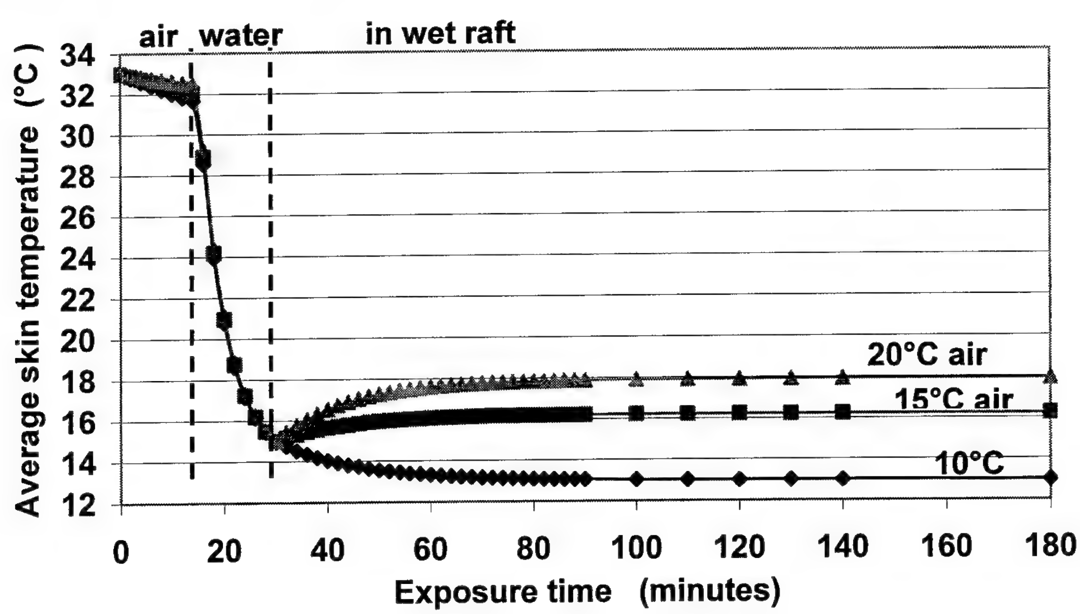

Figure 7d. Air temperature effect on Tsk in air, water and wet raft exposure with 20 km/h wind and 13°C water conditions.

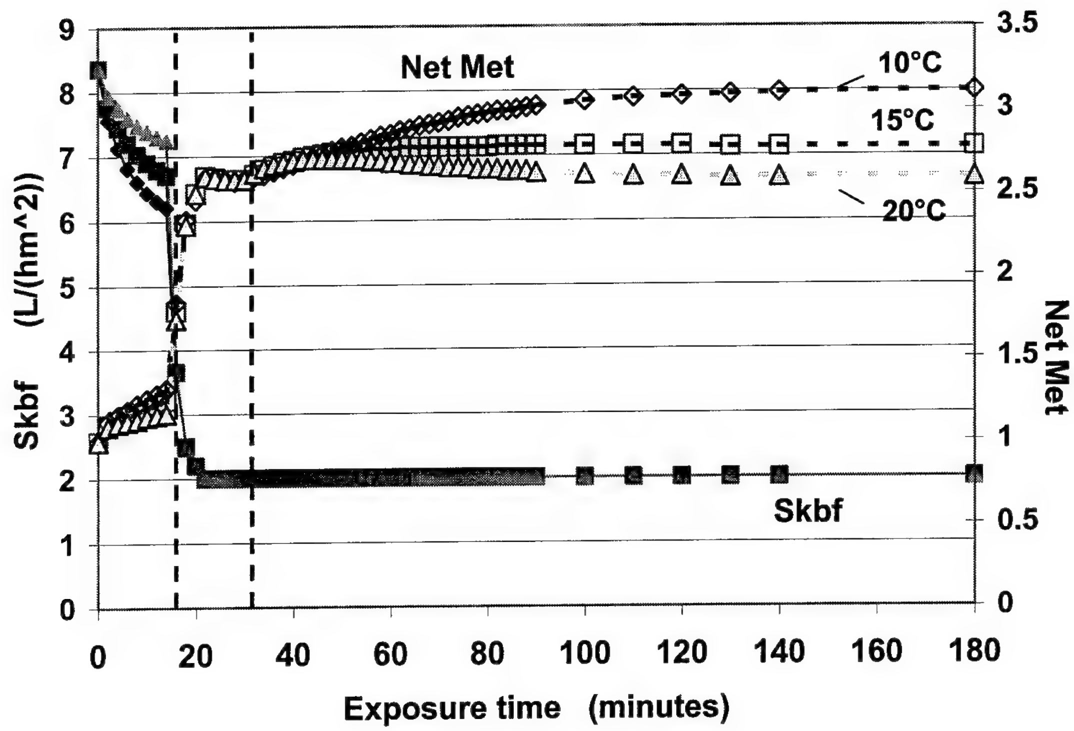

Figure 7e. Air temperature effect on skin blood flow and metabolism for air, water, wet raft series in 20 km/h wind with 13°C sea at 1 met activity level in BDU.

PHYSIOLOGICAL FITNESS AND CARDIOVASCULAR DIFFERENCES

In general, physiologically fit people tend to thermoregulate with more precision. In terms of blood flow to the skin for core cooling, the change in flow per change in body temperature increases with fitness. That is, the gain (Cdil) of the skin blood flow controller increases with fitness.

To reduce core temperature loss in cool and cold conditions blood flow to the skin is constricted. With thermal adaptation to the cold, the maximum vasoconstriction increases so the minimum blood flow to the skin (Skbfmin) is less. A cold adapted person may have a minimum skin blood flow of 1 $L \cdot h^{-1} \cdot m^{-2}$. For this rescue scenario the simulated responses to the warmest (20°C air with 5 km/h wind) and coldest (10°C and 20 km/h wind) are compared with Cdil values of 50 and 200 and Skbfmin of 1 and 2 $L \cdot h^{-1} \cdot m^{-2}$.

Responses to Coldest Condition

The comparison results for the coldest condition (10°C and 20 km/h wind) are displayed in Figures 8 a, b, c and d and those for the warmest condition (20°C air with 5 km/h wind) are in Figures 9 a, b, c and d.

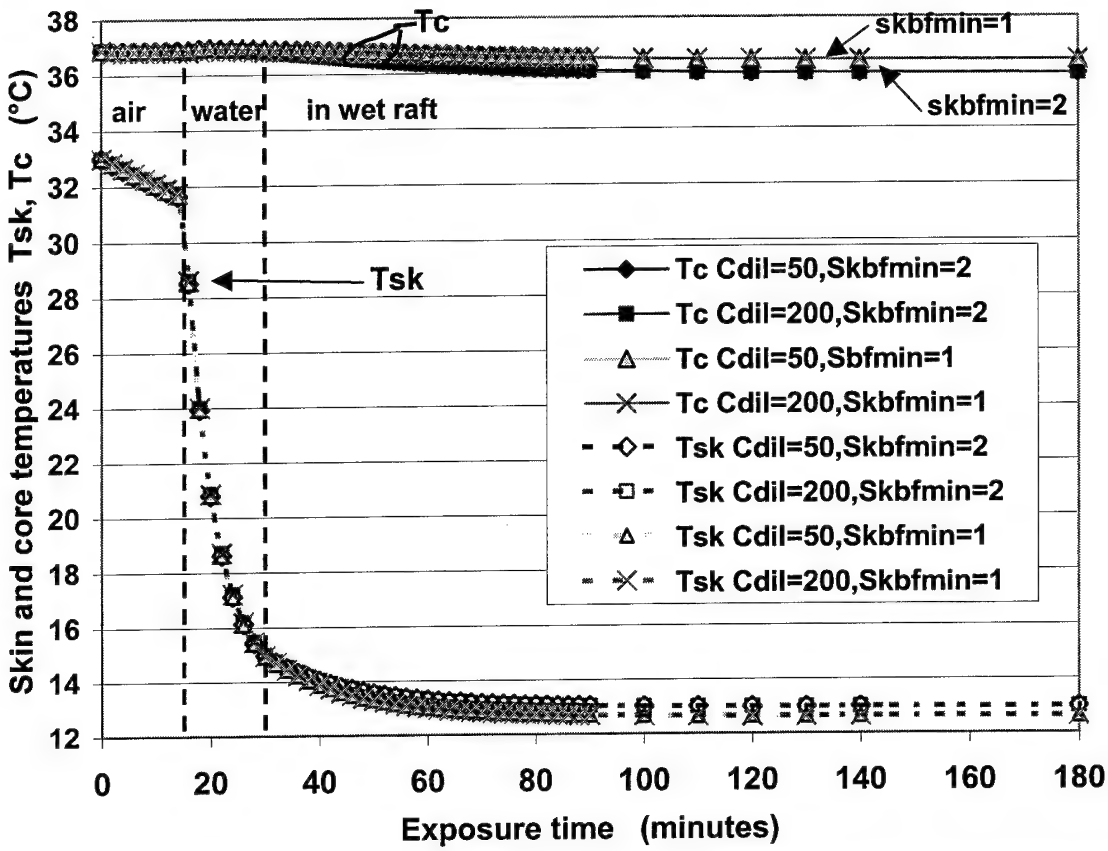

Figure 8a. Effect of cardiovascular simulation parameters Cdil and minimum skin blood flow (Skbfmin) on T_{sk} and Tc for air water wet raft exposure sequence with 1 met activity level in BDU at the coldest condition (10°C, 20 km/h wind and 13°C sea water temperature).

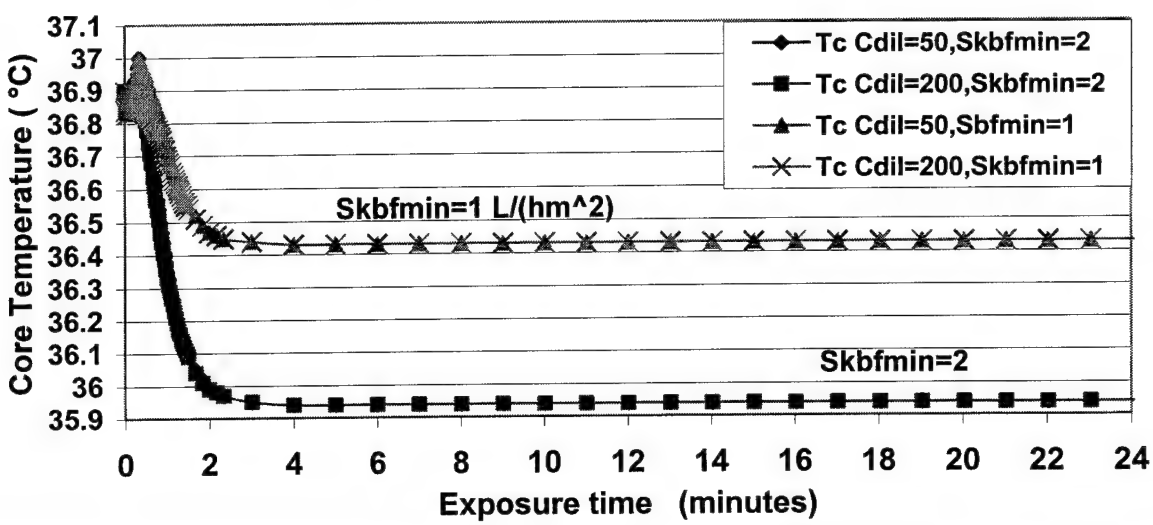

Figure 8b. Effect of cardiovascular parameters (Cdil & Skbfmin) on Tc during a 24 hr long air, water, wet raft exposure sequence at 1 met activity level in BDU at the coldest condition (10°C, 20 km/h wind and 13°C sea water temperature).

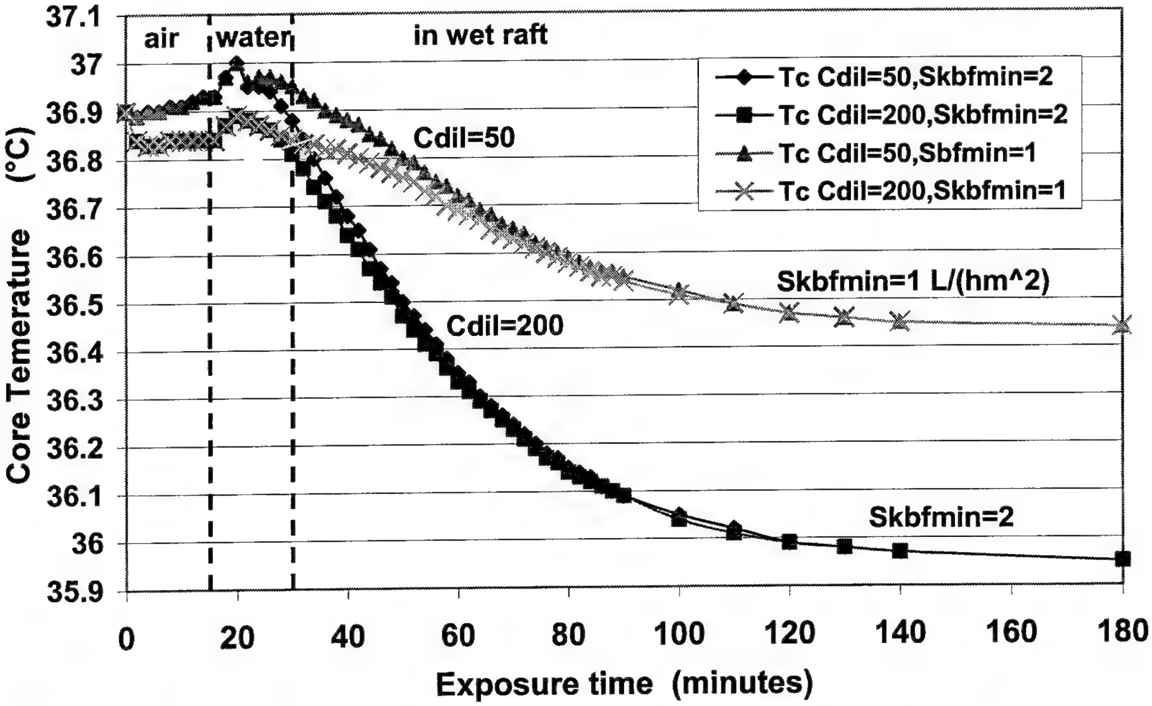

Figure 8c. Effect of cardiovascular parameters Cdil & Skbfmin on Tc during first 180 minutes of air, water, wet raft exposure series at 1 met activity level in BDU at the coldest condition (10°C, 20 km/h wind and 13°C sea water temperature).

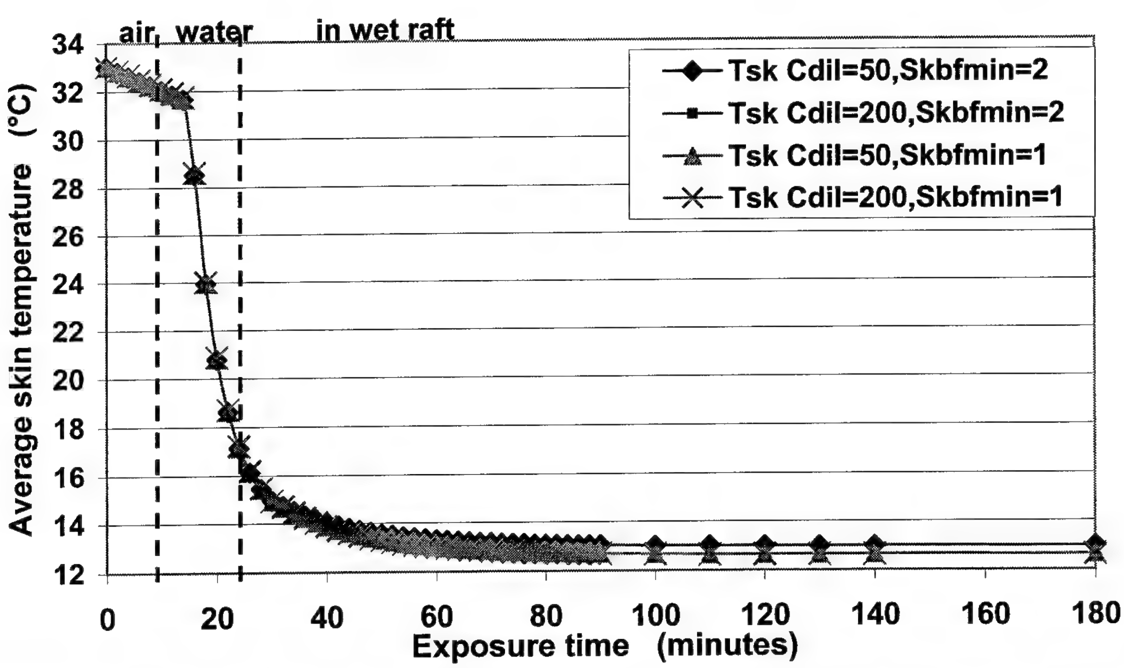

Figure 8d. Effect of Cdil & Skbfmin on Tsk for air, water, wet raft exposure sequence at 1 met activity level in BDU at the coldest condition (10°C, 20 km/h wind and 13°C sea water temperature).

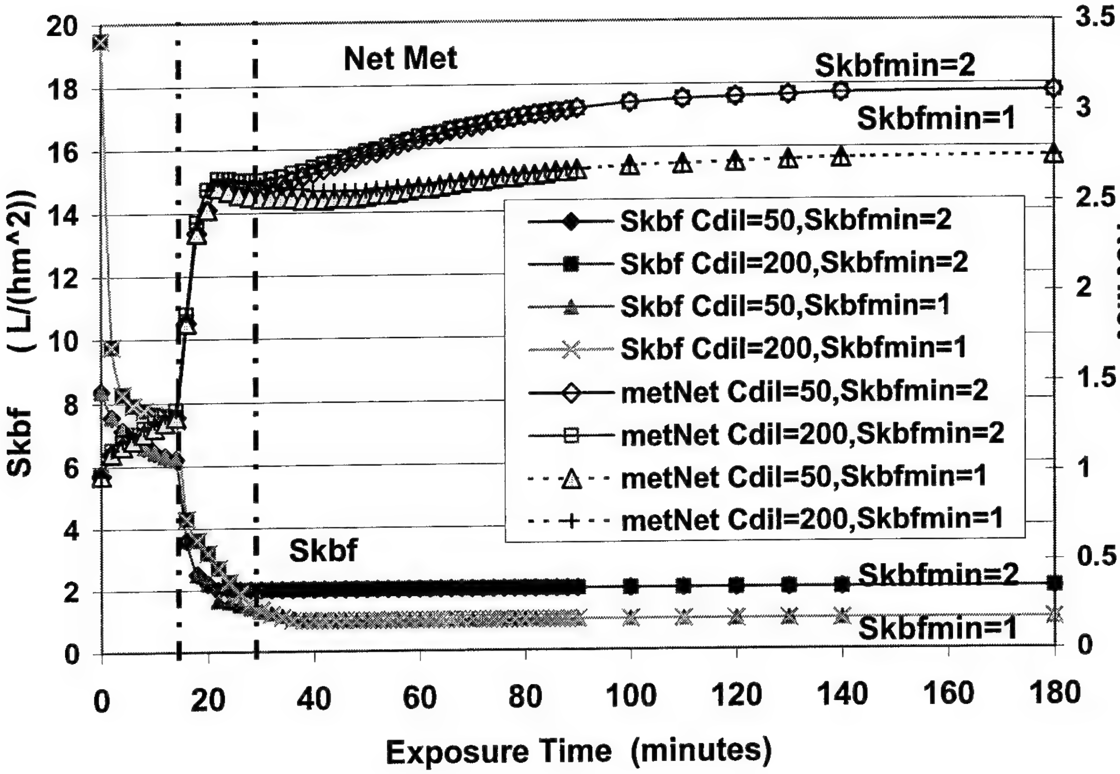

Figure 8e. Effect Cdil and Skbfmin on skin blood flow and metabolism for air, water, wet raft series at the coldest condition (10°C, 20km/h wind).

Responses To Warmest Condition

The simulated responses to the warmest (20°C air with 5 km/h wind) are compared with Cdil values of 50 and 200 $L \cdot h^{-1} \cdot C^{-1} \cdot m^{-2}$ and Skbfmin of 1 and 2 $L \cdot h^{-1} \cdot m^{-2}$.

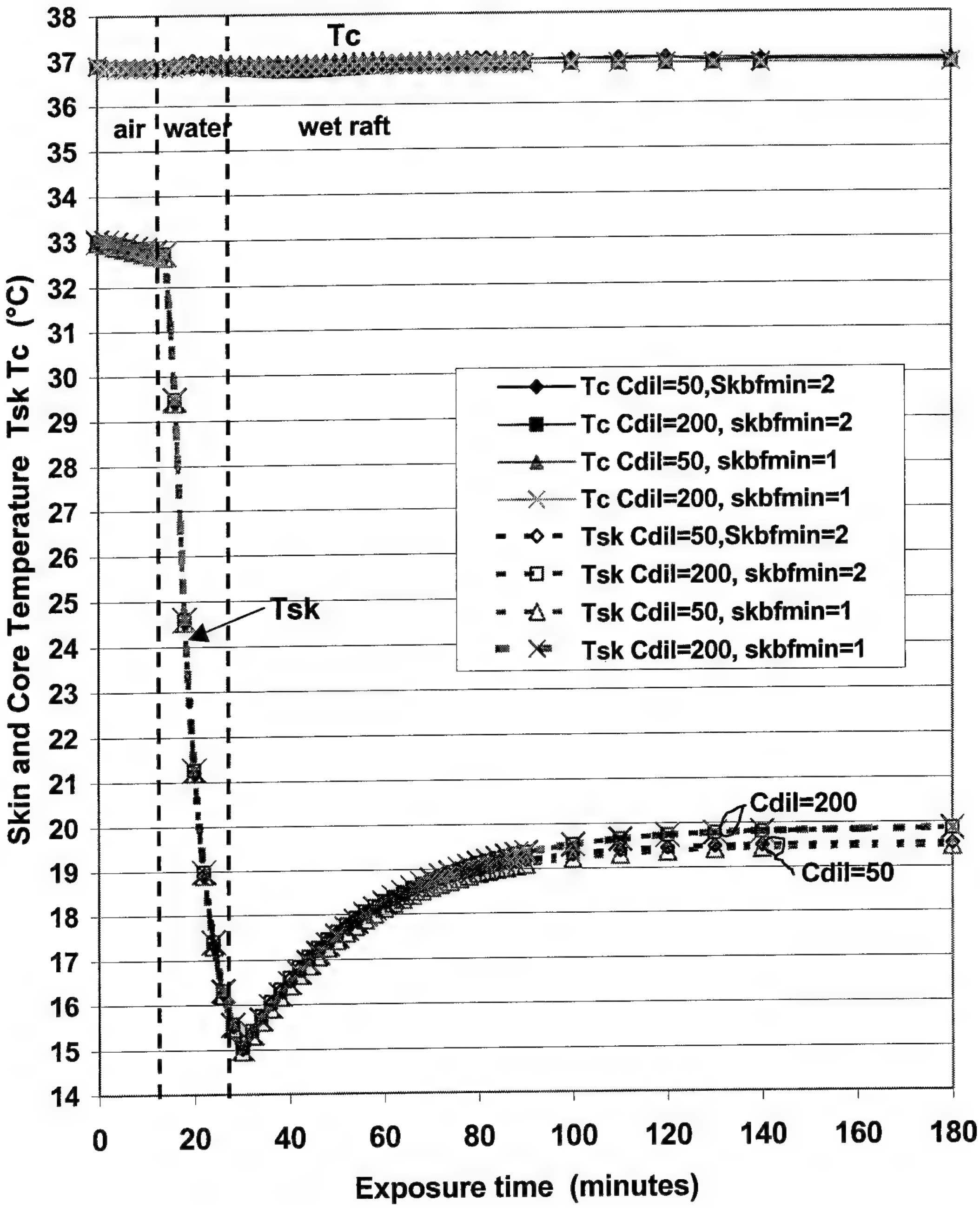

Figure 9a. Effect of cardiovascular simulation parameters Cdil and minimum skin blood flow (Skbfmin) on $\overline{T}_{sk}$ and Tc for air water wet raft exposure sequence with met activity level in BDU at the warmest condition (20°C, 5 km/h wind and 13°C sea).

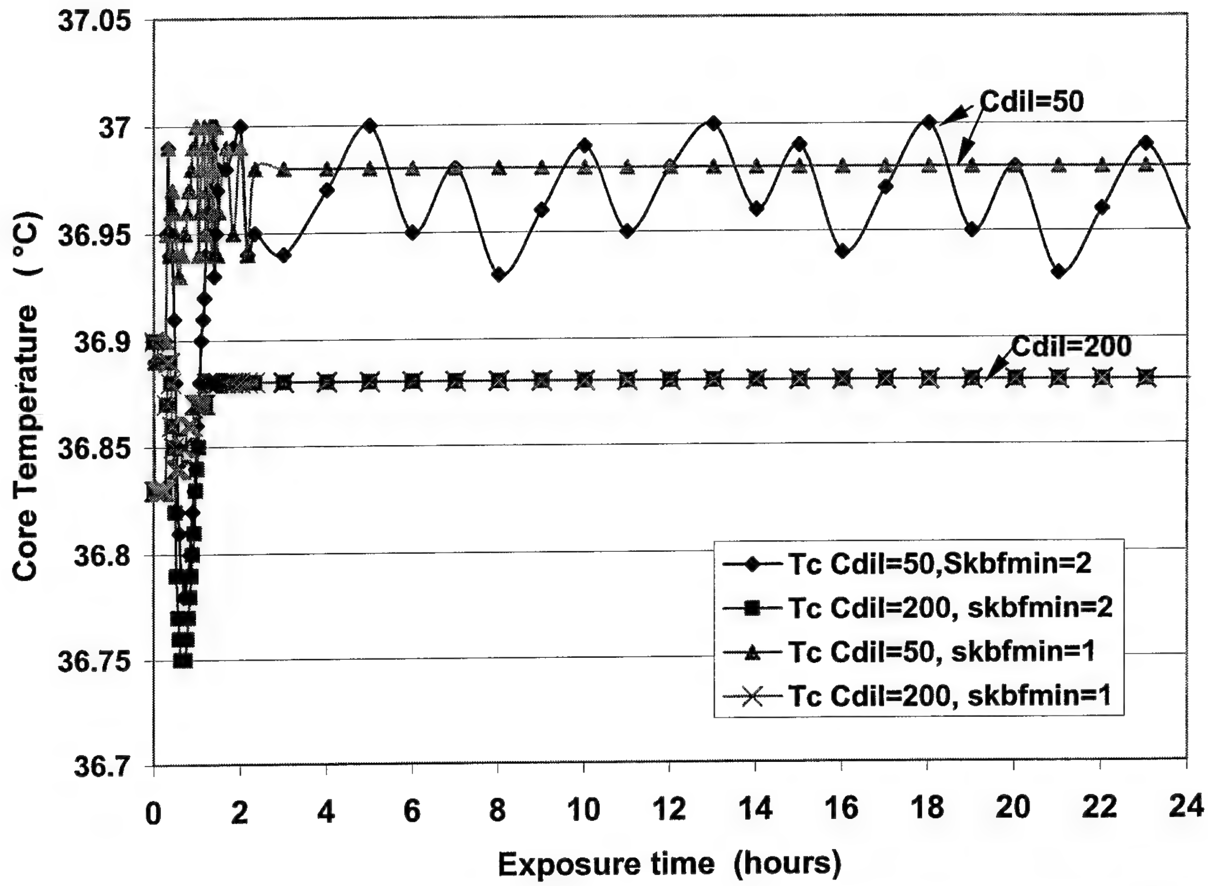

Figure 9b. Effect of cardiovascular variables (Cdil & Skbfmin) on Tc during a 24 hr long air, water, and wet raft exposure sequence at 1 met activity level with the BDU at the warmest condition (20°C, 5 km/h wind and 13°C sea temperature).

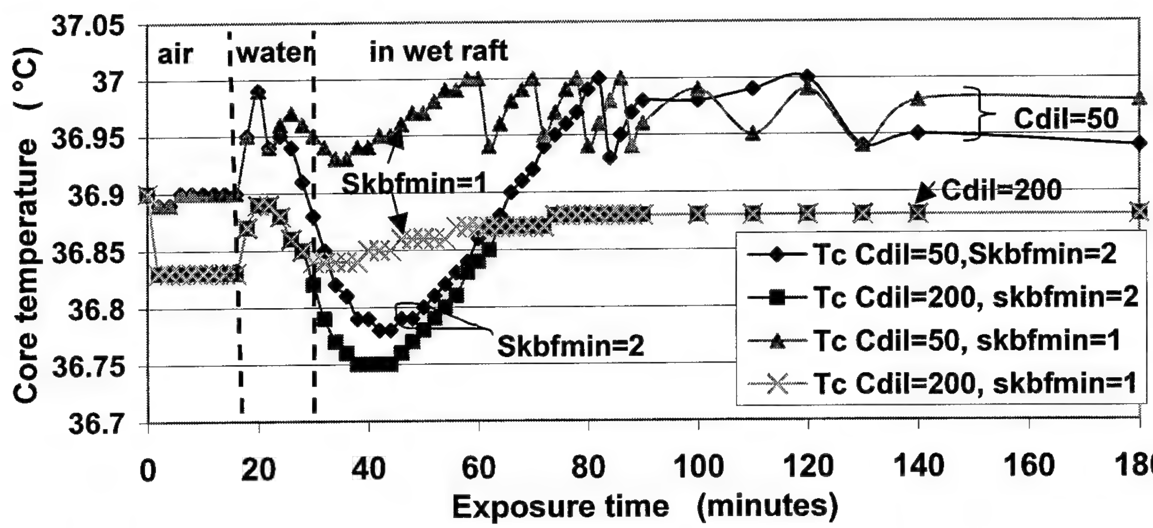

Figure 9c. Effect of cardiovascular parameters Cdil & Skbfmin on Tc during first 180 minutes of air, water, and wet raft sequence at the warmest condition.

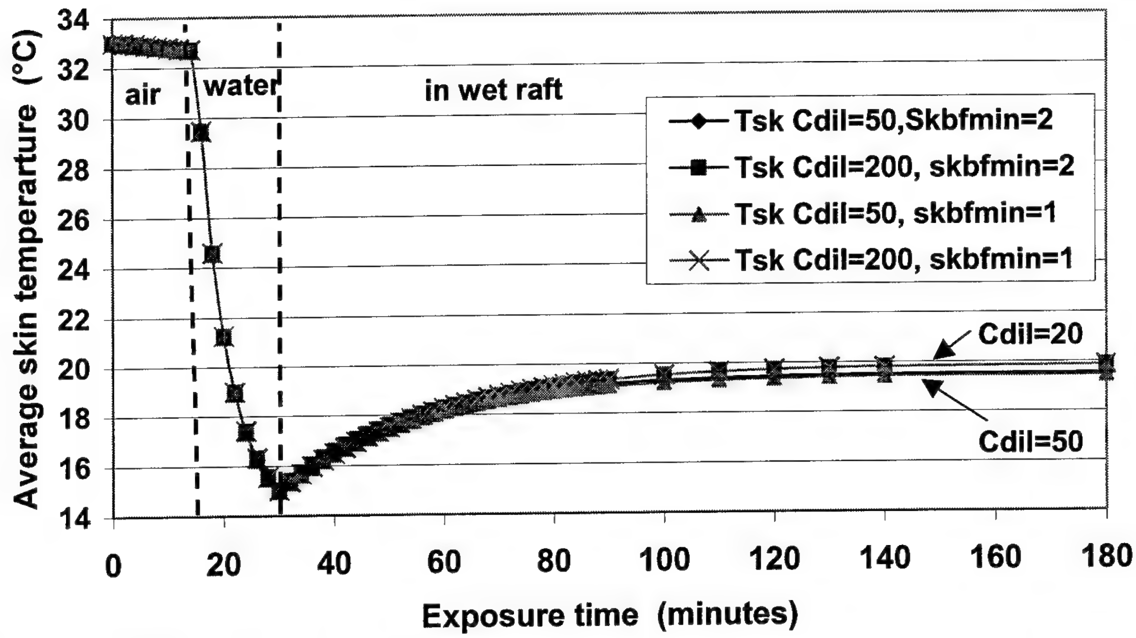

Figure 9d. Effect of Cdil and Skbfmin on Tsk for air, water, and wet raft exposure sequence at 1 met activity level in BDU at the warmest condition (20°C, 5 km/h wind and 13°C sea water temperature).

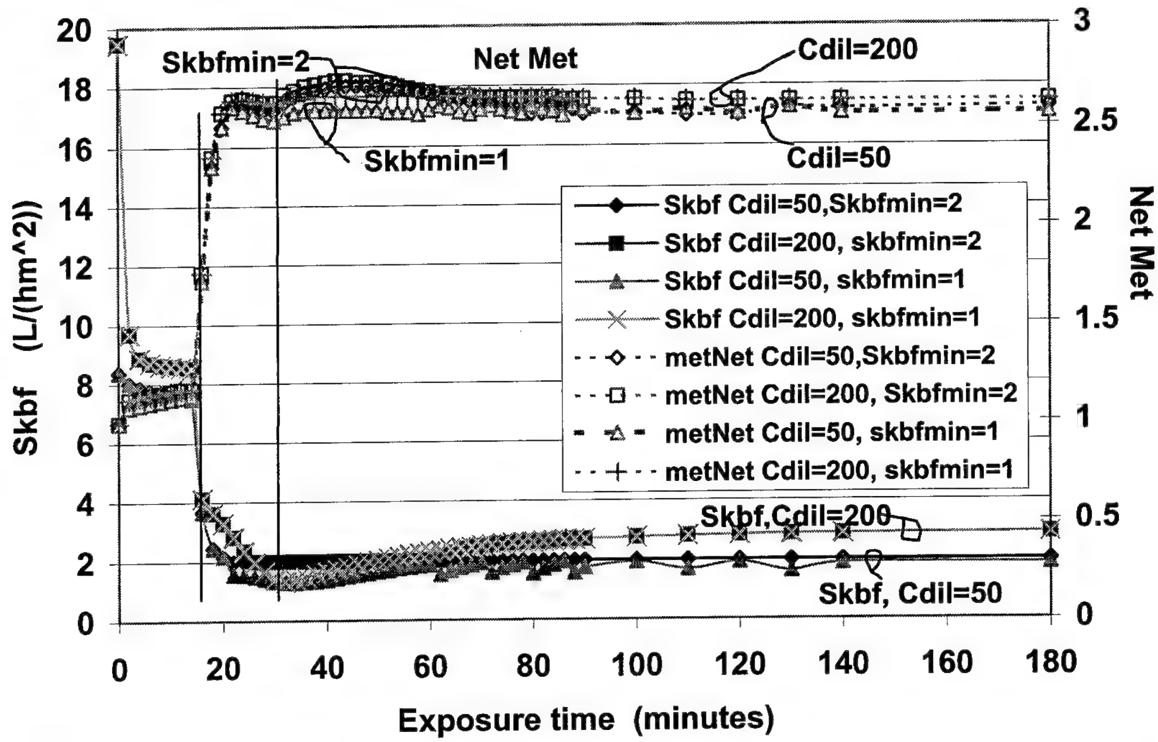

Figure 9e. Effect Cdil and Skbfmin on skin blood flow and metabolism for air, water, and wet raft series at 1 met activity level in BDU at the warmest condition (20°C, 5 km/h wind and 13°C sea).

EFFECTS OF ACTIVITY LEVEL ON SURVIVABILITY

The simulation up to this point has been done assuming that the person is in a resting state throughout the rescue exposure sequence. However in reality, the rescued person is likely working at a higher level before entering the water and in swimming to the raft. To quantify, the effect of increased metabolism before reaching the raft, further simulations were run at the warmest and coldest conditions with the metabolism elevated to 3 times resting (3 met ≅ 315W) during the first 30 minutes. The comparisons for the coldest conditions are displayed in Figures 10a,b, c and d and for the warmest conditions in Figures 11a,b, c and d. The increased met really only affects core temperature and skin blood flow and principally only during the increased activity (shown in Figures 10a,c, d, and 11c,d). The core temperature increase from the exertion getting into the sea and reaching the raft decreases gradually over a period of 60 minutes while resting on the raft.

Coldest Condition

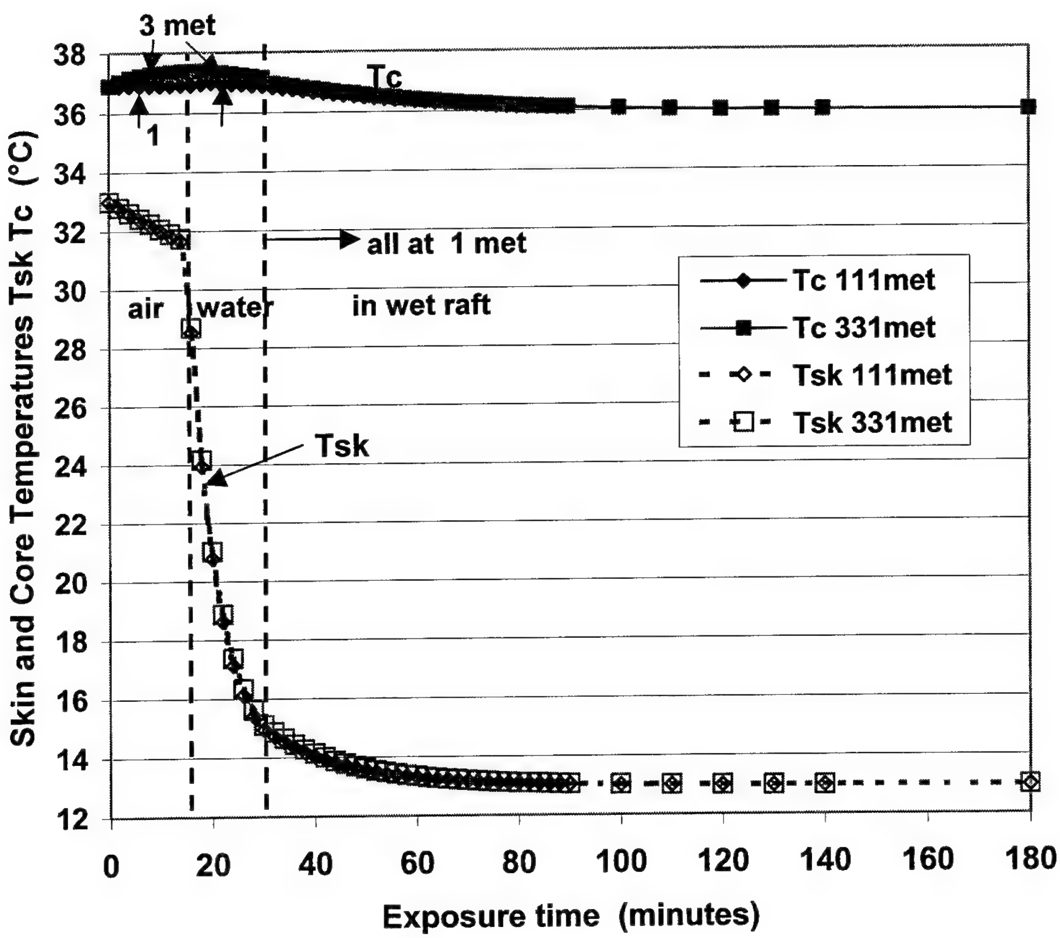

Figure 10a. Effect of activity level on Tsk and Tc prior to entering raft of air, water, wet raft exposure sequence at the coldest condition (10°C, 20 km/h wind). The 331 met designation is for 3 met in air, 3 met in water and 1 met on raft.

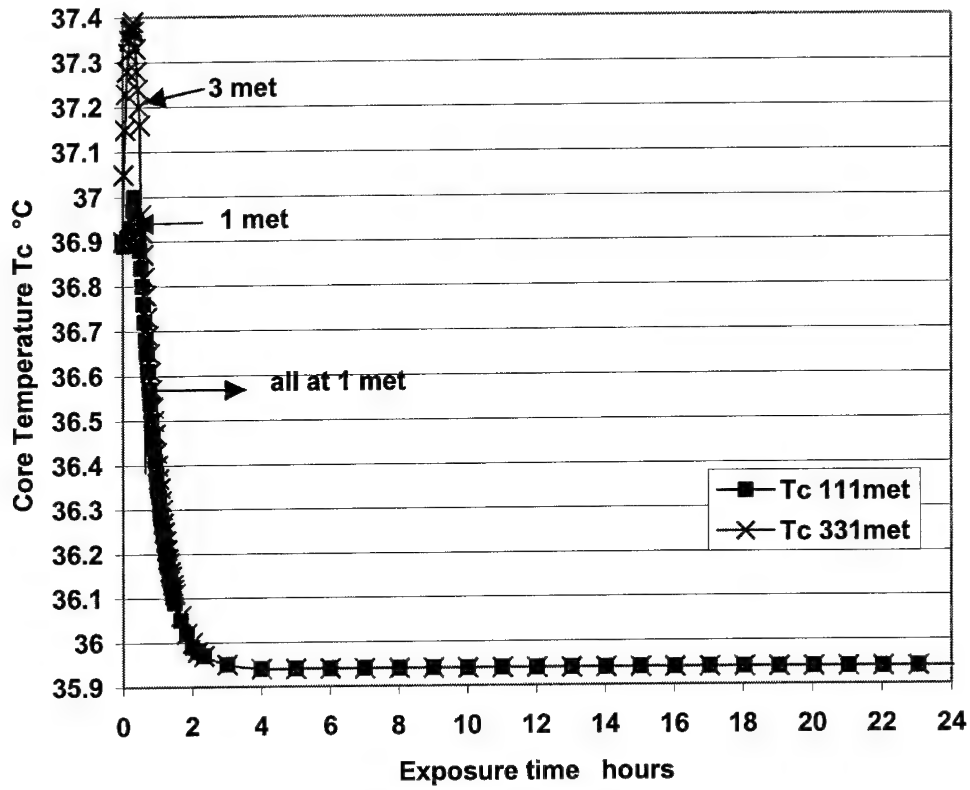

Figure 10b. Effect on Tc over 24 hour period of activity level in air and water prior to resting in wet raft in BDU at the coldest condition (10°C, 20 km/h wind and 13°C sea water temperature).

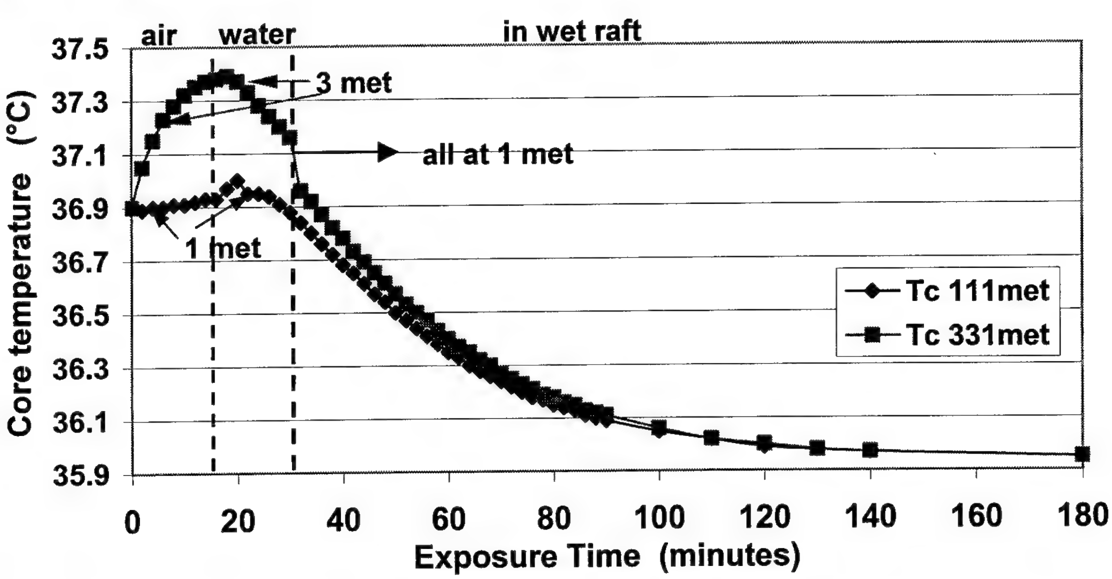

Figure 10c. Effect on Tc of activity level in air and water prior to resting in wet raft with the BDU at the coldest condition (10°C, 20 km/h wind and 13°C sea).

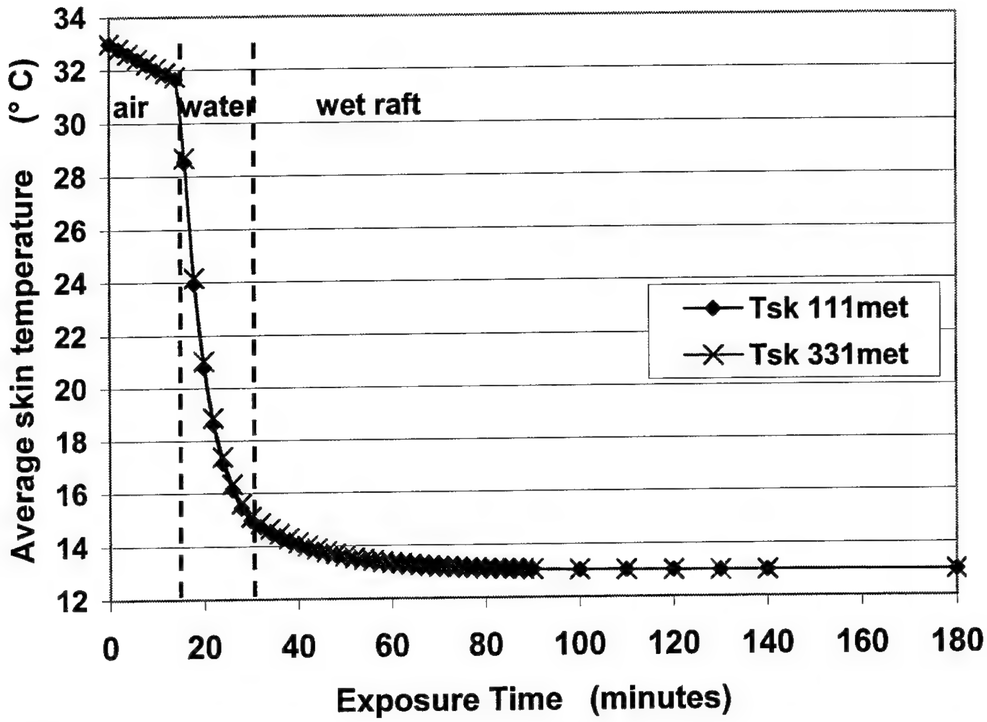

Figure 10d. Effect on $\overline{T}_{sk}$ by increased activity level in air and water prior to resting in wet raft in BDU at the coldest condition (10°C, 20 km/h wind and 13°C sea).

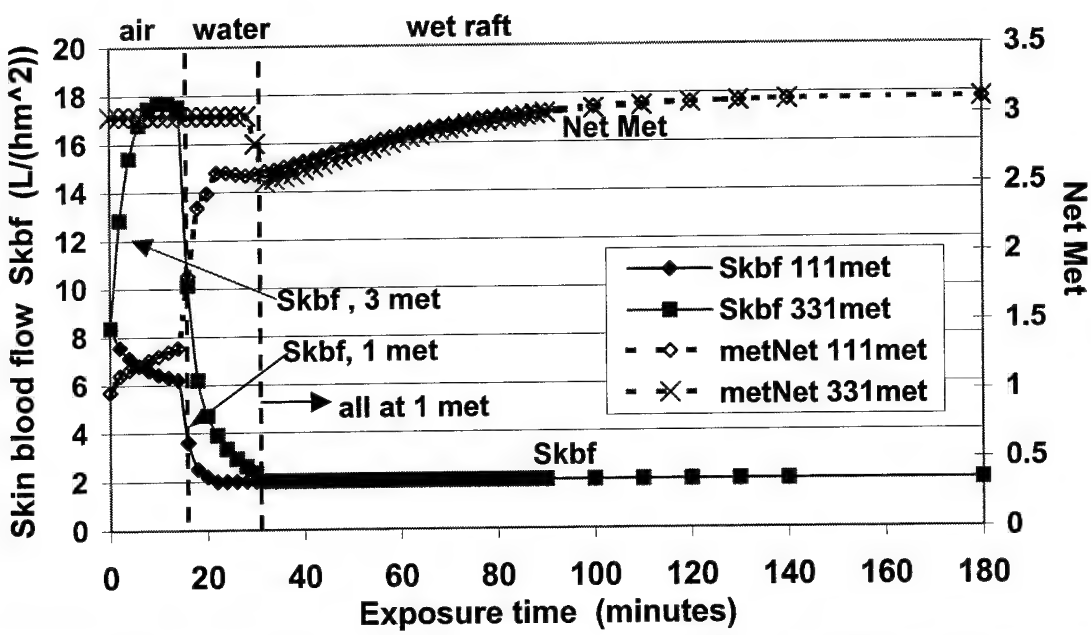

Figure 10e. Effect on Skbf and metabolism by changes in activity level in air and water prior to resting in wet raft with the BDU at the coldest condition (10°C, 20 km/h wind and 13°C sea water temperature).

Warmest Condition

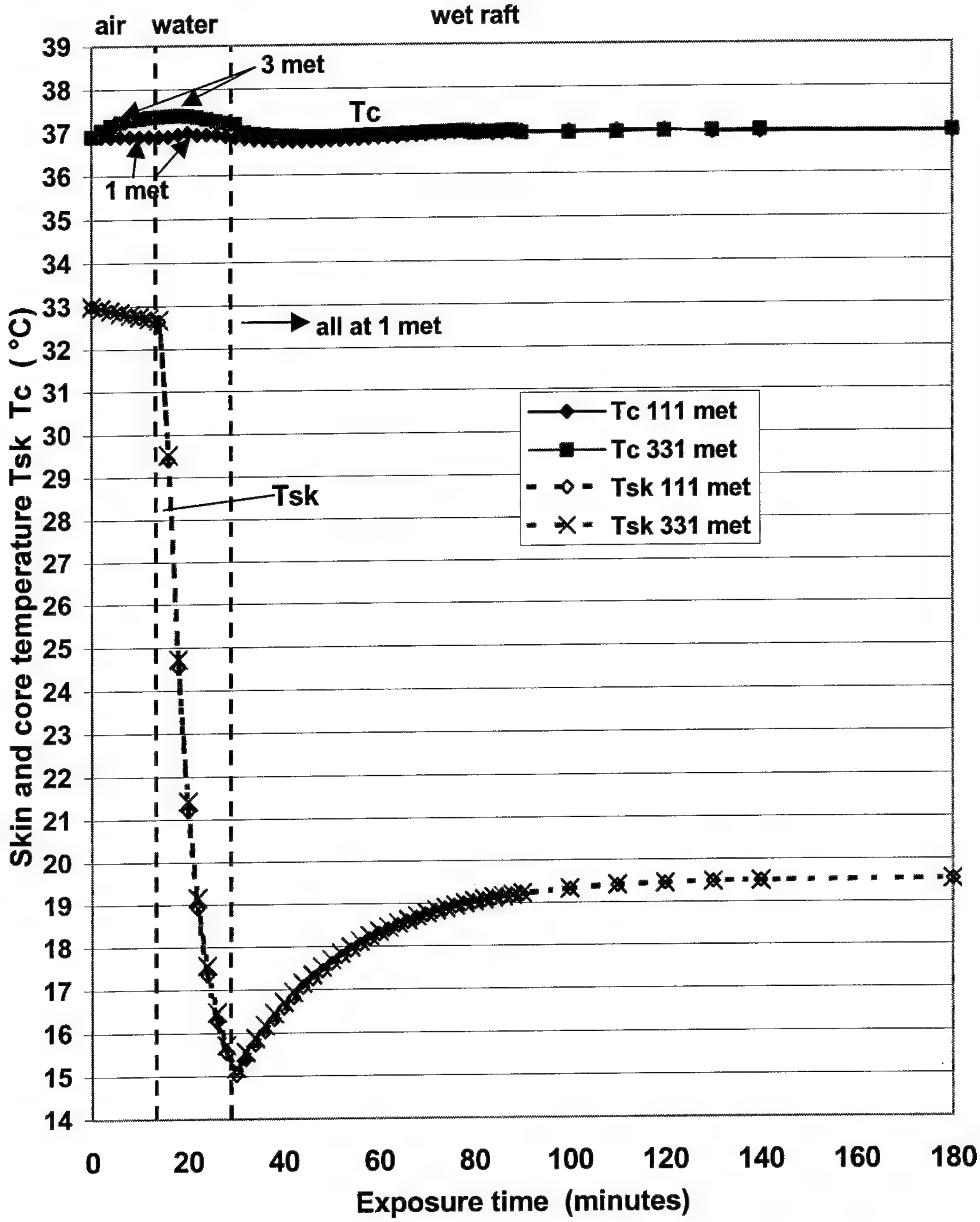

Figure 11a. Effect of activity level on $\overline{T}_{sk}$ and Tc prior to entering raft of air, water wet raft exposure sequence at the warmest condition (20°C, 5 km/h wind).

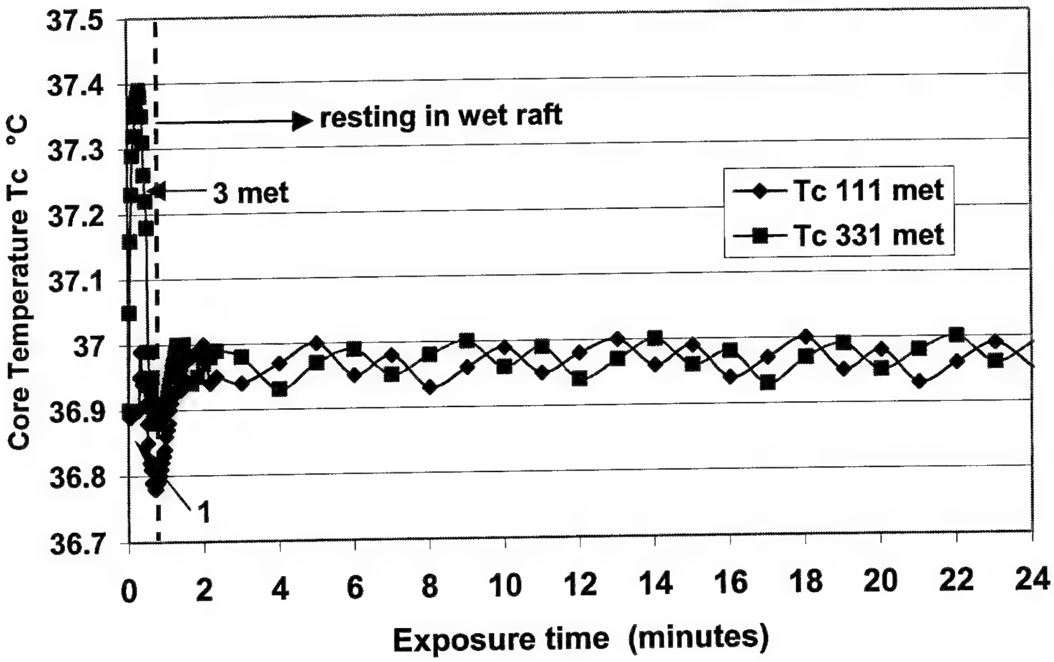

Figure 11b. Effect on Tc over 24 hour period of changes in activity level in air and water prior to resting in wet raft with the BDU at the warmest condition (20°C, 5 km/h wind and 13°C sea water temperature).

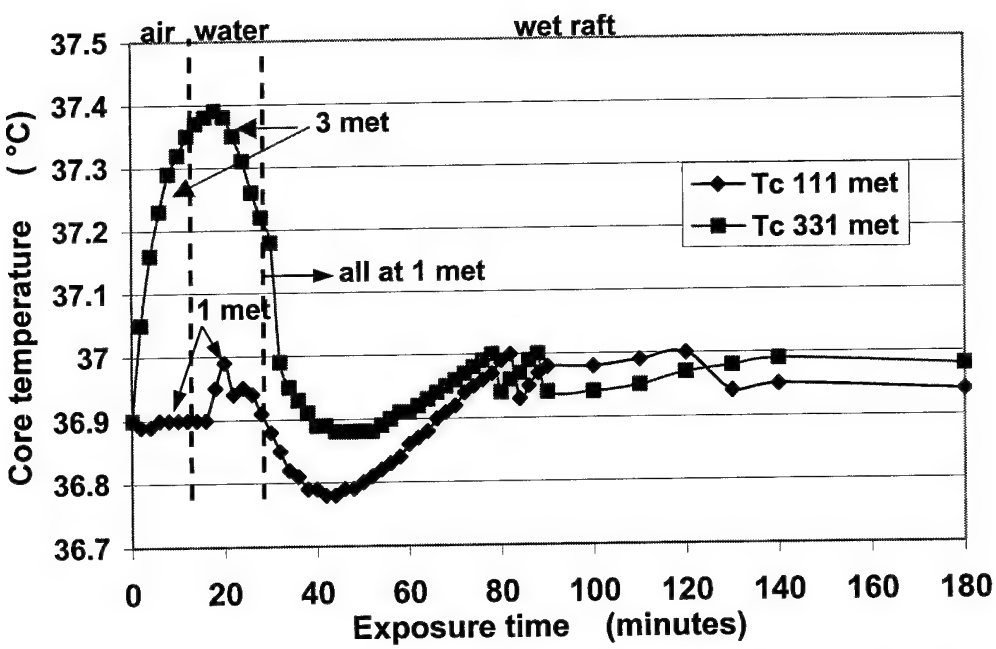

Figure 11c. Effect on Tc of changes in activity level in air and water prior to resting in wet raft with the BDU at the warmest condition (20°C, 5 km/h wind and 13°C sea water temperature).

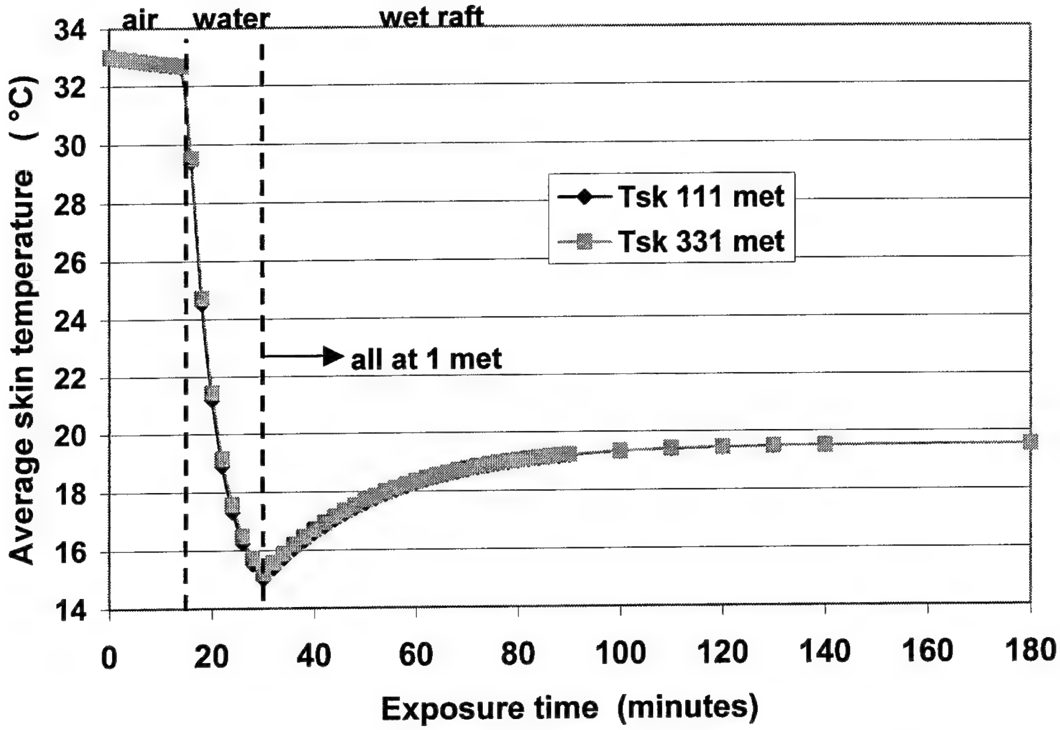

Figure 11d. Effect on $\overline{T}_{sk}$ by changes in activity level in air and water prior to resting in wet raft with the BDU at the warmest condition (20°C, 5 km/h wind).

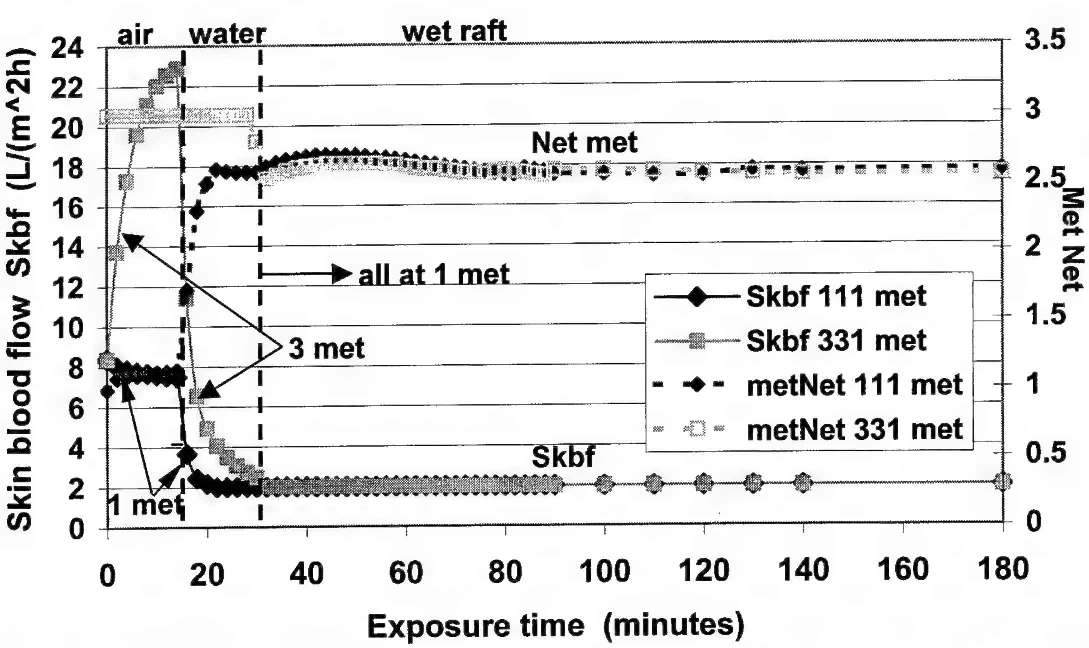

Figure 11e. Effect on Skbf and metabolism to changes in activity level in air and water prior to resting in wet raft with the BDU at the warmest condition.

Experimental Verification

A sea rescue practice maneuver was carried by Israeli Defence Force to compare the predicted and measured results. The core temperatures of the 20 participants were measured with telemetric pills swallowed an hour before they entered the 17°C water and swam 5 minutes to a raft. The air temperature averaged 20.6°C with an RH of 66.4% and wind of 7.4 km/h. The mean pill temperatures are displayed with the predicted core and skin temperatures in Figure 12. The model predicted core temperatures would be stable and the pill measurements verified that.

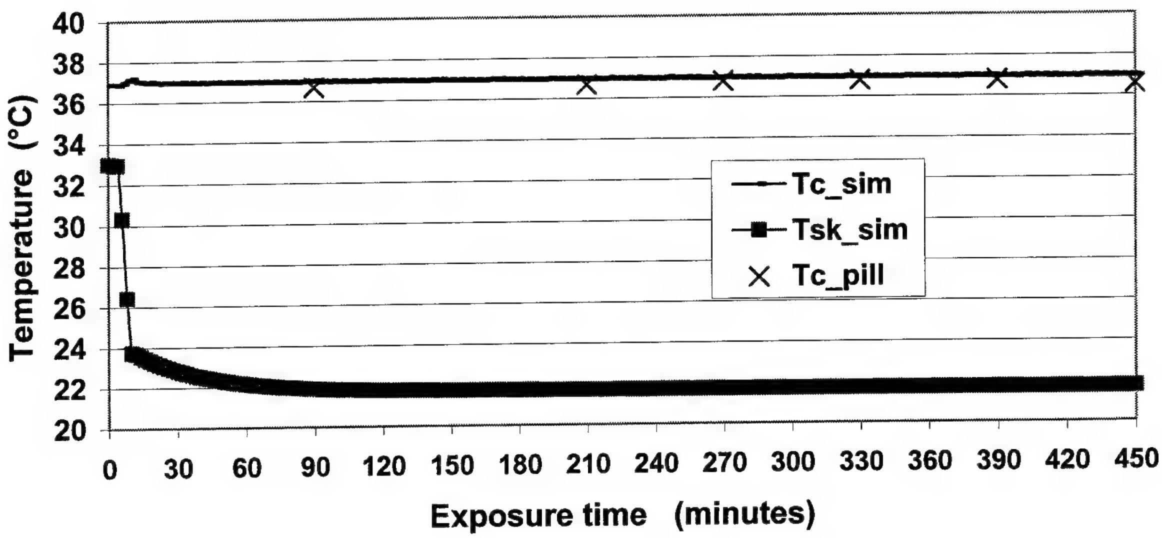

Figure12. Measured mean telemetric pill (Tc_pill) temperatures of 20 paricipants in a sea rescue test in 20.6°C air with 7.4 km/h wind and 17°C water temperature compared to predicted core and skin temperatures for the conditions.

Figure 13 displays the individual subject measurements, the means and the model predictions in an expanded temperature scale. In general, the measured core temperatures of the individuals were quite stable and consistent. However, there is considerable scatter between individuals indicating possible radio signal offset differences between the pills.

The agreement between predicted and measure core temperatures and its stability while resting on the wet raft indicates that the simulated shivering (Figure 14) or extra metabolism necessary to provide these core temperatures is approximately correct (Tikusis, 1999) and can be sustained at these levels for at least 7.5 hours.

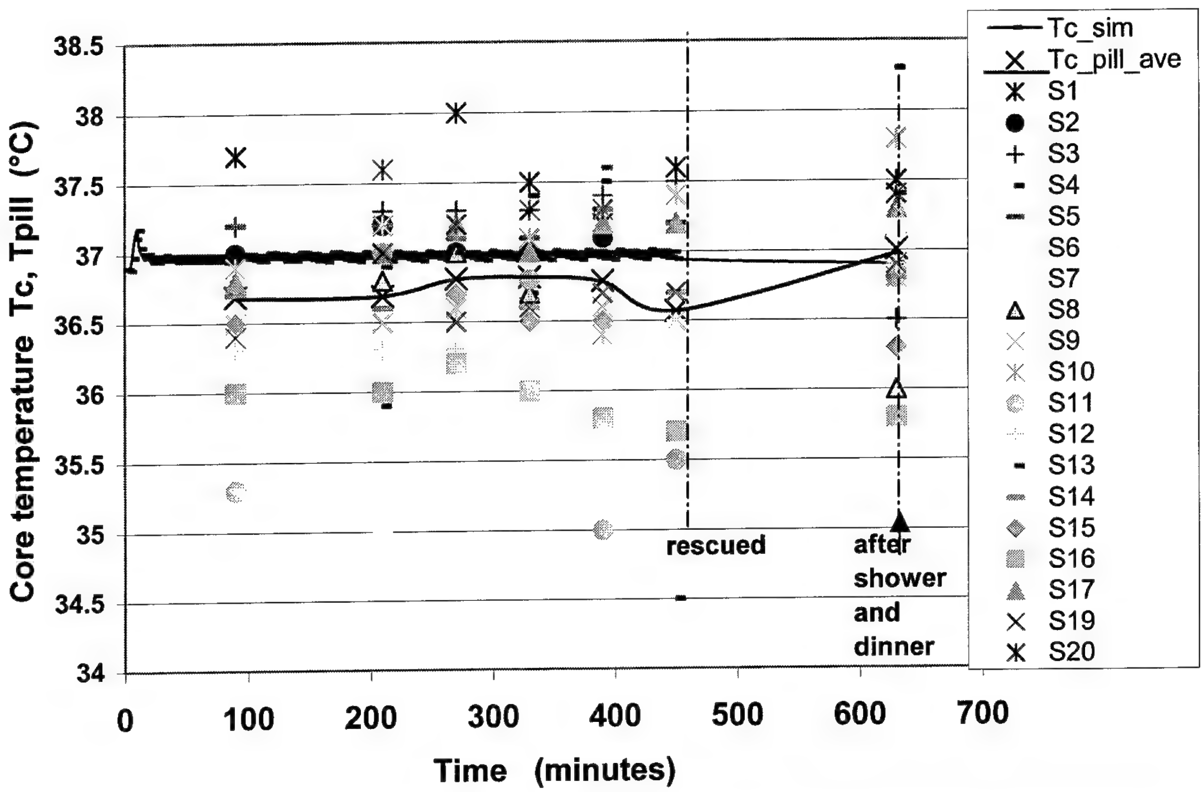

Figure 13. Predicted core temperature compared to core temperature measured with individual radio thermometer pills.

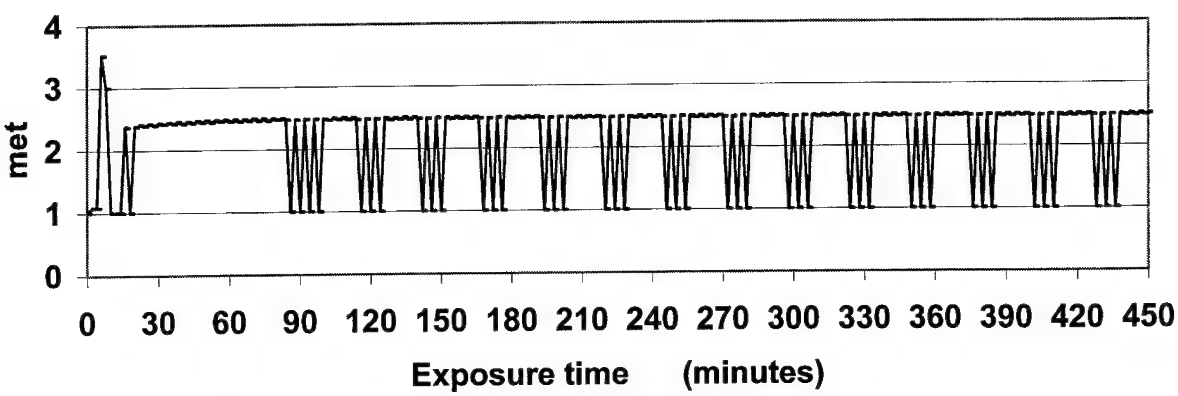

Figure 14. Simulated metabolic response for the sea rescue test.

<u>Disabled Shivering Function</u>

In order to demonstrate the power and importance of prolonged shivering for survival in this cold sea rescue scenario, the simulation was repeated with the shivering function disabled. The core temperature comparison in Figure 15 clearly shows that rescued soldiers could not have survived without shivering.

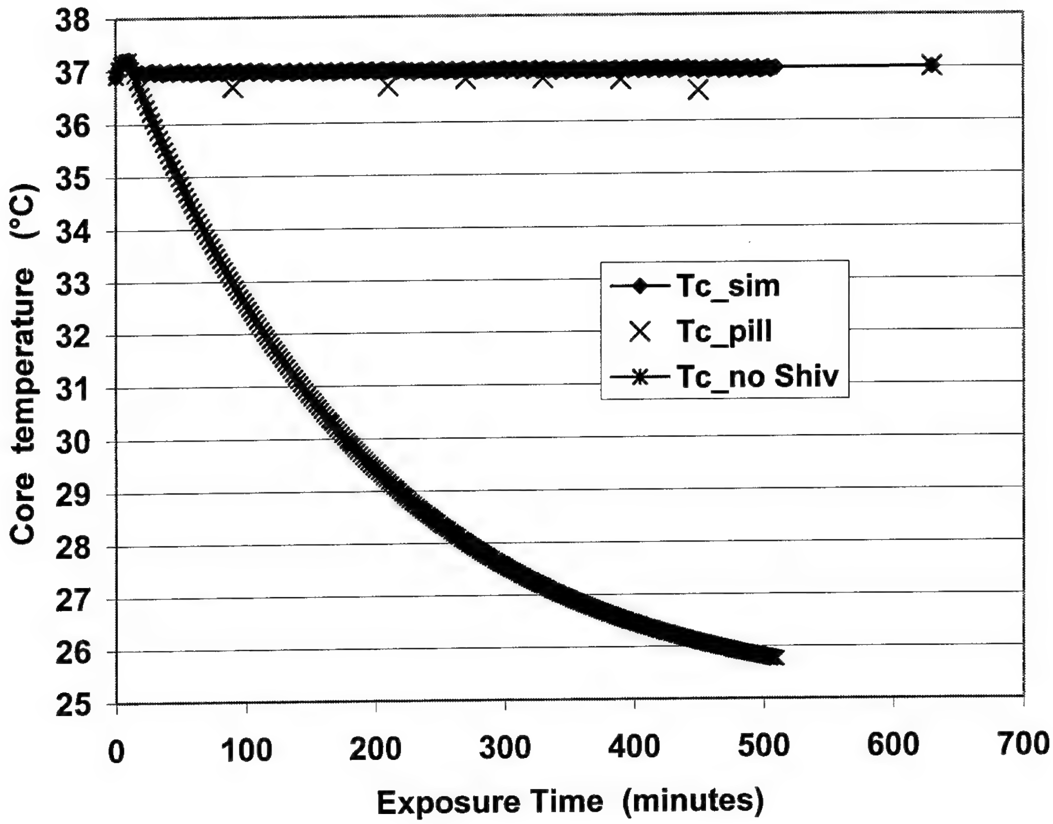

Figure15. Measured mean telemetric pill (tc_pill) temperatures of 20 paricipants in a sea rescue test in 20.6°c air with 7.4 km/h wind and 17°c water temperature compared to predicted core temperatures for the conditions <u>with</u> and <u>without</u> shivering.

DISCUSSION

The simulation results developed in this report appear reasonable and can be helpful for estimating the quantity and time occurrence of hypothermic responses. The predictions depicted by the figures are fairly extensive and describe thermoregulatory responses fairly completely for conditions in the range of 10°C to 20°C air temperatures and 5 – 20 km/h wind speeds. These simulations were made in order to facilitate the users application of conditions that appear in real-life situations during various operations and training requirements. The computer program included can be used as a guide to estimate the hypothermic responses to other non-freezing conditions.

CONCLUSIONS

A rational computer model was developed to simulate situations in typical air, water, and wet raft exposures expected for the Warfighter in cold but non-freezing conditions. The simulation results show that the environmental conditions are dominate factors to consider in any operational sequence. Physiological fitness, thermal adaptation and activity prior to resting on the wet raft have negligible benefits.

From the simulation results it appears hypothermia is not life threatening for the conditions tested if shivering can be maintained. But any impairment or fatigue of the shivering response would reduce the permissible safe exposure time, worsen the hypothermia and increase possibilities for cold injury.

The mild hypothermia shown by this simulation may affect function and certainly cause thermal discomfort, which may decrement other performance factors.

The prediction modeling results also suggest that, for the scope of environmental conditions modeled, the temperature of both water and air are bigger contributors to the hypothermic response than the wind. However, further evaluation is needed to validate this model under different combinations of ambient temperature, water temperature and individual exposure time.

RECOMMENDATIONS

Further observations are suggested to compare simulation results with measured results of real operation, training missions, and prototypical test rescues. A weakness of the model simulations may be with the reasonableness of expecting a persistent non-fatiguing shivering response that allows adequate heat generation response. It is uncertain whether a person can really continue to generate 2 mets of extra heat undiminished for 24 hours. Since it is so crucial to maintain body core temperature (and impacts on limits to cold tolerance and cold injury) in such situations, the shivering fatigue functions of this model need additional verification to improve confidence in its prediction for other more drastic scenarios.

The simulation assumed thermal radiation was with surfaces at air temperature. Solar radiation will reduce hypothermia but night sky radiation will increase hypothermia even further. These effects could easily be added to the model's code for additional completeness.

The clothing compartment's dynamic response features would also be improved if thermal capacitance were added. As used here the weight and thermal capacitance of the clothing were neglected for simplicity and considered as linear approximations.

REFERENCES

1. Gagge, A. P., Fobelets, A., and Berglund, L., G., 1986. A Standard Predictive Index of Human Response. *ASHRAE Transactions*, Vol. 92(2).

2. Gonzalez, Richard R. 1988. Biophysics of Heat Transfer and Clothing Considerations. in *Human Performance and Evironmental Medicine at Terrestrial Extremes*, edited by Pandolf,K.B, Sawka, M. N. and Gonzalez R.R., pp 80-82, Benchmark Press, Indianapolis.

3. Stolwijk, J.A.J and Hardy, J.D. 1966. Temperature regulation in man—A theoretical study. *Pflügers Archiv*: 291.

4.Stolwijk, J.A.J. 1970. A mathematical model of physiological temperature regulation in man. NASA-9-9531. September.

5.Montgomery,L.D. 1972. *Simulation of Heat Transfer in Man under Immersed Conditions.* PhD Disertation, University of California, Los Angeles.

6. Tikusis, P. and Giesbrecht,G.G. , 1999. Prediction of shivering heat production from core and mean skin temperatures. *Eur J Appl Physiol.* 79:221-229.

APPENDIX A

Experimental Verification Data

table 1: Core temperature from telemetric pill

	hour								Recovered
subject	12:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00
1	37.7	37.6	38	37.5	37.2	37.6			37.5
2	37	37.2	37	37	37.1				37.2
3	37.2	37.3	37.3	37.3	37.4	37.5			36.5
4	37.2	35.9	37	36.7	37.5	34.5			38.3
5	37.2	37.2	37.1	37.1	37.3	37.2			37.1
6	36.3	36.1	36.3	36.4	36.5	36.4			37.1
7		35	36.4	36.5	36.5	35.9			37.2
8		36.8	37	36.7	37.2				36
9	36.5	36.5	36.6	36.6	36.6	36.5			36.8
10	36.9	37.2	36.6	37.1	36.4	37.4			37.8
11	35.3	37	36.2	36.8	35	35.5			36.8
12	36.3	36.3	36.3	36.5	36.5	36.5			36.9
13	37	36.9	37	37.4	37.6	37.2			37.4
14	36.7	36.6	36.7	36.6		36.7			36.8
15	36.5	36	36.7	36.5	36.5				36.3
16	36	36	36.2	36	35.8	35.7			35.8
17	36.8	37	37.2	37	37.2	37.2			37.3
19	36.4	37	36.5	36.6	36.7	36.7			36.9
20		37.6	37.2	37.3	37.3				37.4
Average	**36.69**	**36.69**	**36.81**	**36.82**	**36.79**	**36.57**			**37.01**
SD	**0.57**	**0.67**	**0.46**	**0.40**	**0.66**	**0.87**			**0.60**
SE	**0.14**	**0.15**	**0.11**	**0.09**	**0.16**	**0.22**			**0.14**

protocol:		Exposure time minutes
9:30	taking telemetric pill	
10:30	leaving ship:5 min swimming in sea water	0
10:40	climbing on the raft	10
12:00	1st measurement	90
18:00	last measurement	450
19:00	climbing back on the ship	540
21:00	measurements at the ship after a shower and a meal	630

table 2: Environmental measurements

hour	Ta	RH	Va	Twater	km/h
12:00	22.8	66	1.1	17	3.96
13:00	27	46	0.6	17	2.16
14:00	21.2	71	0.5	17	1.8
15:00	19.1	77	4.2	17	15.12
16:00	18.9	64	4.4	17	15.84
17:00	18.3	65	2.2	17	7.92
17:30	18.7	68	1.6	17	5.76
18:00	18.4	74	1.8	17	6.48
ave	**20.55**	**66.375**	**2.05**		**7.38**

Appendix B

Program Listings

```
/*
   Name: Larry Berglund
         Date: 2/20/02
         File: Dani_Air_Water_Wet2nm02.c

         This simulates the thermal response of a person moving through a series
         of 3 constant environments: air, water, air with wetskin and or clothing     .
*/

#include <assert.h>
#include <stdio.h>
#include <math.h>
#include <ctype.h>

#define TTSK 33.7
#define TTCR 36.8
#define TTBM 36.49   /*TTBM=.9*TTCR+.1*TTSK =36.49 */
#define BAR 760.
#define CSW 170.
#define CDIL 50. /* CDIL 200 super athlete, 50 average person */
#define CSTR .5
#define SKBFN 6.3
#define Skbfmax 90.
#define Skbfmin 2.
#define CMIN 5.28
#define CB 1.163
#define DT 0.0167   /* Time step 1/60=.0167 hr */

double SatVapPres(double T);
double Convection(double Xmet, double V);
double Respiration(double Xmet, double Ta, double Pa);
double Shiver(double Tc, double Tsk);
double SkinBloodFlow(double Tc, double Tsk);
double Alpha(double Skbf);
double Sweat(double Tc, double Tsk,double alpha);
void OutputHeader();
double Core(double Tc,double Tsk,double Xmet,double Res,double* hfcsk, double skbf,double* RmNet);
double Skin(double wet,double Dry,double Emax,double* hfcsk);
double Skin_wet_cl(double wet,double Rbound,double Emax,double* hfcsk,double Tcl,double To);

int main (void)
{
        int Envir,steps,step;
        double Ta,Tr,Tdp,RH,Pa,Psk,Pscl,Tcl,To,ET,ETR,Tw, V,hc,Hc,he,He,hr;
        double
wet,Tsk,Tskn,Tc,Tbm,Xmet,We,XmetNet,RmNet,metA,metW,metR,clo,FCL,FACL,Dry,Fpcl;
        double Emax,Esk,Eskin,Edif,Res,EresDryRes,Skbf,alpha,Regsw,Ersw,heatFlowCoreToSkin;
        double
HSCR,HSSK,TCCR,TCSK,Rcl,Rclw,Rbound,Rpcl,Rpbound,time,TIM,durationA,durationW,durationR;
        TIM=0;
        step=0;
        time =0;
        printf("Enter conditions: clo Ta(C) Tr Tdp V(km/h) Tw  ");
        scanf("%lf%lf%lf%lf%lf%lf",&clo,&Ta,&Tr,&Tdp,&V,&Tw);
        V =V*1000/(60*60); /* convert km/h to m/s */
        printf("V=%6.2f m/s\n",V);
```

```
	printf("Enter initial physiology (or 0's if neutral or unknown): wet Tsk Tc ");/* inserts
		default  values if wet,Tsk,Tcr are zero's */
	scanf("%lf%lf%lf",&wet,&Tsk,&Tc);
	printf("Enter exposure durations(h): air water raft steps(min) ");
      /* time is duration in hours, steps is min. between print interval*/
	scanf("%lf%lf%lf%d",&durationA,&durationW,&durationR,&steps);
	time+=durationA;
	if (wet <=0)
		wet=.06;
	if (Tsk <=0)
		Tsk=33;
	if (Tc <=0)
		Tc=36.9;
	printf("Enter exposure met level: air water raft  ");
      /* met is relative acivity, resting met=1, walking=3 */
	scanf("%lf%lf%lf",&metA,&metW,&metR);
	OutputHeader();
We=0;
	Xmet=metA;
	XmetNet=(1-We)*Xmet;
	RmNet=58.2*XmetNet; /* watts/(m^2) */

	Pa=SatVapPres(Tdp); /* vapor press Torr */
	RH=Pa/(SatVapPres(Ta));
	Hc = Convection(Xmet,V); /* convection */
	He=2.2*Hc;  /* evaporation   watts/(m^2 Torr) */
	hr=4.5; /*radiation watts/(m^2 K) */
	To=(hc*Ta + hr*Tr)/(hc+hr);
	FACL=1.0+.2*clo; /* surface area of clothing relative to Adu */
	Rcl=.155*clo; /* clothing thermal resistance m^2 C/watts */
	Rbound=1/((hr+hc)*FACL); /*  boundary layer thermal resistance m^2 C/watts */
	Dry=(Tsk-To)/(Rcl+Rbound);

	for(Envir=0;Envir<=2;Envir++)
	{
	if (Envir==1)
		time+=durationW;
	if (Envir==2)
		time+=durationR;

	while (TIM<time)  /* thermo-physiology loop */
	{
		/* dry and evaporative heat transfer*/
		if (Envir==1)
		{
			Xmet=metW;
			XmetNet=(1-We)*Xmet;
			hc=230;
			hr=0;
			Rclw=Rcl/70;
			To=Tw;
			wet=1;
			Rbound=1/((hc+hr)*FACL);
			Dry=(Tsk-To)/(Rclw+Rbound);
			Tcl=(To*Rclw + Tsk*Rbound)/(Rclw+Rbound);/* steady state analysis */
		}
```

```
else
{
        Rpcl= .153181*clo;
        Psk=SatVapPres(Tsk); /* vapor press Torr */

        if(Envir==0)
                {
                Xmet=metA;
                XmetNet=(1-We)*Xmet;
                hc=Hc;
                Tcl = To +Dry/(FACL*(hr+hc));
                he=He;
                Rpbound=1/(he*FACL);
                Emax=(Psk-Pa)/(Rpcl+Rpbound);
                Fpcl=1/(1+.153181*he*FACL*clo); /*Berglund 1981, for IL=.45*/
                }
        if (Envir==2)
                {
                Xmet=metR;
                XmetNet=(1-We)*Xmet;
                hc= Convection(Xmet,V); /* convection */
                he=2.2*hc;  /* evaporation   watts/(m^2 Torr) */
                Rpbound=1/(he*FACL);
                }

        hr=4*.725*(5.67E-08)*pow(((Tcl+To)/2+273),3); /* corrected hr */
        To=(hc*Ta + hr*Tr)/(hc+hr);
        Rbound=1/((hc+hr)*FACL);
        Dry=(Tsk-To)/(Rcl+Rbound); /* only used for Envir=0 */
}

/* Thermal Physiology */
Res = Respiration(Xmet,Ta,Pa);

Skbf=SkinBloodFlow(Tc,Tsk); /* Liters/(h m^2) */
alpha=Alpha(Skbf);
Regsw=Sweat(Tc,Tsk,alpha); /*g/(h m^2) */
if (Envir==1)
        {
        Emax=0;
        }
else
        {
        if (Envir==2)
                {
                Pscl=SatVapPres(Tcl);
                Emax=he*FACL*(Pscl-Pa);
                wet=1;
                Tcl=(Tsk*Rbound+To*Rclw-wet*Emax*Rclw*Rbound)/(Rclw+Rbound);
/*steady state, wet clothing        */
                }
        else  /* Envir=0 */
                {
                Ersw=.68*Regsw;  /* watts/m^2 */
                wet=Regsw/Emax;
                if (wet>=1)
```

```
                                        wet=1;
                                Esk=(.06+.94*wet)*Emax;
                                Edif = (1-wet)*.06*Emax;
                                }
                        }
                HSCR = Core(Tc,Tsk,XmetNet,Res,&heatFlowCoreToSkin,Skbf,&RmNet);
                if(Envir==2)
                        HSSK = Skin_wet_cl(wet,Rbound,Emax,&heatFlowCoreToSkin,Tcl,To);
                else
                        HSSK = Skin(wet,Dry,Emax,&heatFlowCoreToSkin);

                if (step%steps==0)
                printf(" %5d %11.2f %6d %6.2f %6.2f %6.2f %6.2f %6.2f %6.2f %9.2f
\n",Envir,TIM,step,Tc,Tsk,Tcl,Skbf,RmNet/58.2,
                                Regsw/60,wet);

                /* thermal capacity */
                TCCR=.97*(1-alpha)*70;
                TCSK=.97*alpha*70;
                /* stepwise integration */
                Tc +=HSCR*1.8/TTCR*DT;
                Tsk +=HSSK*1.8/TTSK*DT;
                TIM +=DT;
                step +=1;
                }
        }
        return 0;
}

void OutputHeader()
{
        printf("\nEnvironment time(h)  min.  Tc    Tsk   Tcl   Skbf   metNet sw g/m^2min wet\n");
}

double SatVapPres(double T)
{
        double Pst;
                Pst = exp(18.6686-(4030.183/(T+235.)));
        return Pst;
}

double Convection(double Xmet,double V)
{
        double CHCA, CHCV, CHCmin, hc;
        CHCmin = 3.0;
        CHCA = 5.66*pow((Xmet - 0.85),0.39); /* hc due to activity */
        CHCV = 8.6*pow(V,0.53);             /* hc due to air speed V in m/s */
                if (CHCV >= CHCmin)
                        ;
                else
                        (CHCV = CHCmin);
                if (CHCV >= CHCA)
                        hc = CHCV;
                else
                        hc = CHCA;
        return hc;
```

```
}

double Respiration(double Xmet, double Ta, double Pa)
{
        double RM,Res,Eres,Cres;
        RM = 58.2*Xmet;
        Eres = 0.0023*RM*(44.-Pa);  /* watts/m2 */
        Cres = 0.0014*RM*(34.-Ta);  /* watts/m2 */
        Res = Eres + Cres;
        return Res;
}

double Shiver(double Tc, double Tsk) /* Tikusis & Stolwijk Models */
{
        double shiver,BF;
        shiver=0; BF=15; /* BF is % body fat */
        if (Tc<37 && Tsk<33)
                shiver=(156*(37-Tc)+47*(33-Tsk)-1.57*pow((33-
Tsk),2))/pow(BF,0.5);/*Tikusis,1999,15%BF*/
/*      if (Tc<TTCR && Tsk<TTSK)        /* Stolwijk */
/*              shiver = 19.4*(Tc-TTCR)*(Tsk-TTSK);
*/
 return shiver;
}

double SkinBloodFlow(double Tc, double Tsk)
{
        double Colds=0;
        double Skbf, WarmC=0;
        if (Tsk<TTSK)
                Colds=TTSK-Tsk;
        if (Tc>TTCR)
                WarmC=Tc-TTCR;
        Skbf=(SKBFN+CDIL*WarmC)/(1+CSTR*Colds);
        if (Skbf>Skbfmax)
                Skbf= Skbfmax;
        if (Skbf<Skbfmin)
                Skbf= Skbfmin;
        return Skbf;
}

double Alpha(double Skbf)
{
        double alpha;
        alpha=0.04177+.74518/(Skbf+0.585417);
        return alpha;
}

double Sweat(double Tc, double Tsk, double alpha)
{
        double regsw, Tmb;
        regsw=0;
        Tmb=(1-alpha)*Tc + alpha*Tsk;
                if ((Tmb>TTBM)&&(Tsk>TTSK))
                        regsw=CSW*(Tmb-TTBM)*exp((Tsk-TTSK)/10.7);
                else if ((Tmb>TTBM)&&(Tsk<=TTSK))
```

```
                        regsw=CSW*(Tmb-TTBM);
        if (regsw>667)
                regsw=667;  /* regsw_max=667g/(h m^2)=11.1g/(min m^2)!=20g/(min m^2) */
        return regsw;
}

double Core(double Tc,double Tsk,double XmetNet,double Res,double*heatFlowCoreToSkin, double
Skbf, double*RmNet)
{
        double RmetNet,Hfcrsk,HSCR,shiver;
   shiver=Shiver(Tc,Tsk);          /* watts/m^2 */
        Hfcrsk=(CMIN+CB*Skbf)*(Tc-Tsk);  /* watts/m^2 */
        RmetNet = 58.2*XmetNet + shiver;  /* metabolic heat produced watts/m^2 */
        HSCR=RmetNet-Hfcrsk-Res;          /* rate of heat storage in core  watts/m^2 */
        *heatFlowCoreToSkin=Hfcrsk;
        *RmNet=RmetNet;
        return HSCR;
}

double Skin(double wet,double Dry,double Emax,double*heatFlowCoreToSkin )
{
        double Esw,Ediff,Esk,HSSK;
        Esw=wet*Emax;
        Ediff=.06*(1-wet)*Emax;
        Esk=Esw+Ediff;
        HSSK=*heatFlowCoreToSkin-Dry-Esk; /* rate of heat storage in skin watts/m^2 */
        return HSSK;
}

double Skin_wet_cl(double wet,double Rbound,double Emax,double*heatFlowCoreToSkin,double
Tcl,double To)
{
        double Escl,Dry,HSSK;
        Escl=wet*Emax; /*evaporation from clothing*/
        Dry=(Tcl-To)/Rbound;
        HSSK=*heatFlowCoreToSkin-Dry-Escl; /*at steady state heat flow from skin = heat flow from
clothing */
        return HSSK;
}

/* This is the End */

/* output is pasted below
report data

air 28F, water 40F, 5 met through-out, 20 min in air, 5 min in water, 10 minutes in wet clothing.
Enter conditions: clo Ta(C) Tr Tdp V(km/h) Tw  .7 -2 -2 -4 20 4
V=  5.56 m/s
Enter initial physiology (or 0's if neutral or unknown): wet Tsk Tc 0 0 0
Enter exposure durations(h): air water raft steps .33 .083 .166 1
Enter exposure met level: air water raft  5 5 5

Envir   time(h) min. Tc     Tsk    Tcl   Skbf  metNet sw     wet
                                                      g/m^2min
  0      0.00    0  36.90  33.00  8.95  8.37  5.00  0.00    0.00
  0      0.02    1  37.06  32.82  6.60 13.26  5.00  0.46    0.10
```

```
0    0.03    2 37.19 32.65  6.57 16.82  5.00 0.89   0.20
0    0.05    3 37.30 32.47  6.53 19.36  5.00 1.21   0.28
0    0.07    4 37.39 32.30  6.48 21.17  5.00 1.46   0.34
0    0.08    5 37.47 32.14  6.44 22.41  5.00 1.66   0.39
0    0.10    6 37.54 31.98  6.40 23.25  5.00 1.82   0.43
0    0.12    7 37.60 31.82  6.36 23.78  5.00 1.95   0.46
0    0.13    8 37.64 31.67  6.32 24.08  5.00 2.05   0.49
0    0.15    9 37.69 31.52  6.29 24.21  5.00 2.13   0.51
0    0.17   10 37.72 31.38  6.25 24.22  5.00 2.20   0.53
0    0.18   11 37.75 31.24  6.22 24.13  5.00 2.24   0.55
0    0.20   12 37.78 31.10  6.18 23.97  5.00 2.28   0.57
0    0.22   13 37.80 30.96  6.15 23.77  5.00 2.31   0.58
0    0.23   14 37.82 30.83  6.11 23.52  5.00 2.33   0.59
0    0.25   15 37.84 30.70  6.08 23.26  5.00 2.34   0.59
0    0.27   16 37.85 30.57  6.05 22.97  5.00 2.34   0.60
0    0.28   17 37.86 30.45  6.02 22.68  5.00 2.35   0.61
0    0.30   18 37.88 30.33  5.99 22.39  5.00 2.34   0.61
0    0.32   19 37.89 30.21  5.96 22.09  5.00 2.33   0.61
1    0.33   20 37.90 30.09 22.55 21.79  5.00 2.32   1.00
1    0.35   21 37.90 25.97 19.62 12.64  5.00 0.69   1.00
1    0.37   22 37.91 22.53 17.17  9.41  5.00 0.00   1.00
1    0.38   23 37.91 19.67 15.14  7.73  5.00 0.00   1.00
1    0.40   24 37.90 17.29 13.45  6.68  5.00 0.00   1.00
2    0.42   25 37.89 15.32 13.94  5.96  5.00 0.00   1.00
2    0.43   26 37.87 14.77 13.39  5.70  5.00 0.00   1.00
2    0.45   27 37.85 14.22 12.89  5.45  5.00 0.00   1.00
2    0.47   28 37.82 13.70 12.42  5.23  5.00 0.00   1.00
2    0.48   29 37.80 13.21 11.98  5.02  5.00 0.00   1.00
2    0.50   30 37.78 12.75 11.56  4.84  5.00 0.00   1.00
2    0.52   31 37.76 12.31 11.17  4.66  5.00 0.00   1.00
2    0.53   32 37.75 11.89 10.79  4.50  5.00 0.00   1.00
2    0.55   33 37.73 11.50 10.43  4.35  5.00 0.00   1.00
2    0.57   34 37.71 11.13 10.09  4.21  5.00 0.00   1.00
Press any key to continue

*/
```

With Shiver disabled

Enter conditions: clo Ta(C) Tr Tdp V(km/h) Tw .7 20.6 20.6 14 7.4 17
V= 2.06 m/s
Enter initial physiology (or 0's if neutral or unknown): wet Tsk Tc 0 0 0
Enter exposure durations(h): air water raft steps(min) 0 .1666 9 2
Enter exposure met level: air water raft 1 3 1

Envir	time(h)	min.	Tc	Tsk	Tcl	Skbf	metNet	sw g/m^2min	wet
1	0.00	0	36.90	33.00	28.38	8.37	3.00	0.00	1.00
1	0.03	2	37.05	28.24	24.99	4.99	3.00	0.00	1.00
1	0.07	4	37.13	24.98	22.68	4.29	3.00	0.00	1.00
1	0.10	6	37.18	22.76	21.10	3.92	3.00	0.00	1.00
1	0.13	8	37.20	21.24	20.02	3.66	3.00	0.00	1.00
2	0.17	10	37.21	20.20	19.97	3.46	1.00	0.00	1.00
2	0.20	12	37.05	20.19	19.94	2.41	1.00	0.00	1.00
2	0.23	14	36.92	20.14	19.89	2.00	1.00	0.00	1.00
2	0.27	16	36.80	20.09	19.84	2.00	1.00	0.00	1.00
2	0.30	18	36.68	20.03	19.80	2.00	1.00	0.00	1.00
2	0.33	20	36.56	19.99	19.75	2.00	1.00	0.00	1.00
2	0.37	22	36.44	19.94	19.71	2.00	1.00	0.00	1.00
2	0.40	24	36.32	19.90	19.67	2.00	1.00	0.00	1.00
2	0.43	26	36.20	19.86	19.64	2.00	1.00	0.00	1.00
2	0.47	28	36.08	19.82	19.60	2.00	1.00	0.00	1.00
2	0.50	30	35.97	19.79	19.57	2.00	1.00	0.00	1.00
2	0.53	32	35.85	19.76	19.54	2.00	1.00	0.00	1.00
2	0.57	34	35.74	19.73	19.51	2.00	1.00	0.00	1.00
2	0.60	36	35.63	19.70	19.48	2.00	1.00	0.00	1.00
2	0.63	38	35.52	19.67	19.46	2.00	1.00	0.00	1.00
2	0.67	40	35.41	19.64	19.43	2.00	1.00	0.00	1.00
2	0.70	42	35.30	19.62	19.41	2.00	1.00	0.00	1.00
2	0.73	44	35.19	19.59	19.39	2.00	1.00	0.00	1.00
2	0.77	46	35.08	19.57	19.36	2.00	1.00	0.00	1.00
2	0.80	48	34.97	19.54	19.34	2.00	1.00	0.00	1.00
2	0.84	50	34.87	19.52	19.32	2.00	1.00	0.00	1.00
2	0.87	52	34.77	19.50	19.30	2.00	1.00	0.00	1.00
2	0.90	54	34.66	19.48	19.29	2.00	1.00	0.00	1.00
2	0.94	56	34.56	19.46	19.27	2.00	1.00	0.00	1.00
2	0.97	58	34.46	19.44	19.25	2.00	1.00	0.00	1.00
2	1.00	60	34.36	19.42	19.23	2.00	1.00	0.00	1.00
2	1.04	62	34.26	19.41	19.22	2.00	1.00	0.00	1.00
2	1.07	64	34.16	19.39	19.20	2.00	1.00	0.00	1.00
2	1.10	66	34.06	19.37	19.18	2.00	1.00	0.00	1.00
2	1.14	68	33.97	19.35	19.17	2.00	1.00	0.00	1.00
2	1.17	70	33.87	19.34	19.15	2.00	1.00	0.00	1.00
2	1.20	72	33.78	19.32	19.14	2.00	1.00	0.00	1.00
2	1.24	74	33.69	19.31	19.12	2.00	1.00	0.00	1.00
2	1.27	76	33.59	19.29	19.11	2.00	1.00	0.00	1.00
2	1.30	78	33.50	19.28	19.09	2.00	1.00	0.00	1.00
2	1.34	80	33.41	19.26	19.08	2.00	1.00	0.00	1.00
2	1.37	82	33.32	19.25	19.07	2.00	1.00	0.00	1.00
2	1.40	84	33.24	19.23	19.05	2.00	1.00	0.00	1.00
2	1.44	86	33.15	19.22	19.04	2.00	1.00	0.00	1.00
2	1.47	88	33.06	19.20	19.03	2.00	1.00	0.00	1.00
2	1.50	90	32.98	19.19	19.01	2.00	1.00	0.00	1.00

2	1.54	92	32.89	19.18	19.00	2.00	1.00	0.00	1.00
2	1.57	94	32.81	19.16	18.99	2.00	1.00	0.00	1.00
2	1.60	96	32.72	19.15	18.98	2.00	1.00	0.00	1.00
2	1.64	98	32.64	19.14	18.97	2.00	1.00	0.00	1.00
2	1.67	100	32.56	19.12	18.95	2.00	1.00	0.00	1.00
2	1.70	102	32.48	19.11	18.94	2.00	1.00	0.00	1.00
2	1.74	104	32.40	19.10	18.93	2.00	1.00	0.00	1.00
2	1.77	106	32.32	19.09	18.92	2.00	1.00	0.00	1.00
2	1.80	108	32.24	19.07	18.91	2.00	1.00	0.00	1.00
2	1.84	110	32.17	19.06	18.90	2.00	1.00	0.00	1.00
2	1.87	112	32.09	19.05	18.89	2.00	1.00	0.00	1.00
2	1.90	114	32.01	19.04	18.87	2.00	1.00	0.00	1.00
2	1.94	116	31.94	19.03	18.86	2.00	1.00	0.00	1.00
2	1.97	118	31.87	19.01	18.85	2.00	1.00	0.00	1.00
2	2.00	120	31.79	19.00	18.84	2.00	1.00	0.00	1.00
2	2.04	122	31.72	18.99	18.83	2.00	1.00	0.00	1.00
2	2.07	124	31.65	18.98	18.82	2.00	1.00	0.00	1.00
2	2.10	126	31.58	18.97	18.81	2.00	1.00	0.00	1.00
2	2.14	128	31.51	18.96	18.80	2.00	1.00	0.00	1.00
2	2.17	130	31.44	18.95	18.79	2.00	1.00	0.00	1.00
2	2.20	132	31.37	18.94	18.78	2.00	1.00	0.00	1.00
2	2.24	134	31.30	18.93	18.77	2.00	1.00	0.00	1.00
2	2.27	136	31.23	18.92	18.76	2.00	1.00	0.00	1.00
2	2.30	138	31.17	18.91	18.75	2.00	1.00	0.00	1.00
2	2.34	140	31.10	18.90	18.74	2.00	1.00	0.00	1.00
2	2.37	142	31.04	18.89	18.73	2.00	1.00	0.00	1.00
2	2.40	144	30.97	18.88	18.72	2.00	1.00	0.00	1.00
2	2.44	146	30.91	18.87	18.72	2.00	1.00	0.00	1.00
2	2.47	148	30.84	18.86	18.71	2.00	1.00	0.00	1.00
2	2.51	150	30.78	18.85	18.70	2.00	1.00	0.00	1.00
2	2.54	152	30.72	18.84	18.69	2.00	1.00	0.00	1.00
2	2.57	154	30.66	18.83	18.68	2.00	1.00	0.00	1.00
2	2.61	156	30.60	18.82	18.67	2.00	1.00	0.00	1.00
2	2.64	158	30.54	18.81	18.66	2.00	1.00	0.00	1.00
2	2.67	160	30.48	18.80	18.65	2.00	1.00	0.00	1.00
2	2.71	162	30.42	18.79	18.65	2.00	1.00	0.00	1.00
2	2.74	164	30.36	18.78	18.64	2.00	1.00	0.00	1.00
2	2.77	166	30.31	18.77	18.63	2.00	1.00	0.00	1.00
2	2.81	168	30.25	18.76	18.62	2.00	1.00	0.00	1.00
2	2.84	170	30.19	18.76	18.61	2.00	1.00	0.00	1.00
2	2.87	172	30.14	18.75	18.61	2.00	1.00	0.00	1.00
2	2.91	174	30.08	18.74	18.60	2.00	1.00	0.00	1.00
2	2.94	176	30.03	18.73	18.59	2.00	1.00	0.00	1.00
2	2.97	178	29.97	18.72	18.58	2.00	1.00	0.00	1.00
2	3.01	180	29.92	18.71	18.57	2.00	1.00	0.00	1.00
2	3.04	182	29.87	18.70	18.57	2.00	1.00	0.00	1.00
2	3.07	184	29.81	18.70	18.56	2.00	1.00	0.00	1.00
2	3.11	186	29.76	18.69	18.55	2.00	1.00	0.00	1.00
2	3.14	188	29.71	18.68	18.54	2.00	1.00	0.00	1.00
2	3.17	190	29.66	18.67	18.54	2.00	1.00	0.00	1.00
2	3.21	192	29.61	18.67	18.53	2.00	1.00	0.00	1.00
2	3.24	194	29.56	18.66	18.52	2.00	1.00	0.00	1.00
2	3.27	196	29.51	18.65	18.52	2.00	1.00	0.00	1.00
2	3.31	198	29.46	18.64	18.51	2.00	1.00	0.00	1.00
2	3.34	200	29.42	18.63	18.50	2.00	1.00	0.00	1.00
2	3.37	202	29.37	18.63	18.49	2.00	1.00	0.00	1.00

2	3.41	204	29.32	18.62	18.49	2.00	1.00	0.00	1.00
2	3.44	206	29.27	18.61	18.48	2.00	1.00	0.00	1.00
2	3.47	208	29.23	18.61	18.47	2.00	1.00	0.00	1.00
2	3.51	210	29.18	18.60	18.47	2.00	1.00	0.00	1.00
2	3.54	212	29.14	18.59	18.46	2.00	1.00	0.00	1.00
2	3.57	214	29.09	18.58	18.45	2.00	1.00	0.00	1.00
2	3.61	216	29.05	18.58	18.45	2.00	1.00	0.00	1.00
2	3.64	218	29.01	18.57	18.44	2.00	1.00	0.00	1.00
2	3.67	220	28.96	18.56	18.44	2.00	1.00	0.00	1.00
2	3.71	222	28.92	18.56	18.43	2.00	1.00	0.00	1.00
2	3.74	224	28.88	18.55	18.42	2.00	1.00	0.00	1.00
2	3.77	226	28.83	18.54	18.42	2.00	1.00	0.00	1.00
2	3.81	228	28.79	18.54	18.41	2.00	1.00	0.00	1.00
2	3.84	230	28.75	18.53	18.41	2.00	1.00	0.00	1.00
2	3.87	232	28.71	18.53	18.40	2.00	1.00	0.00	1.00
2	3.91	234	28.67	18.52	18.39	2.00	1.00	0.00	1.00
2	3.94	236	28.63	18.51	18.39	2.00	1.00	0.00	1.00
2	3.97	238	28.59	18.51	18.38	2.00	1.00	0.00	1.00
2	4.01	240	28.55	18.50	18.38	2.00	1.00	0.00	1.00
2	4.04	242	28.52	18.49	18.37	2.00	1.00	0.00	1.00
2	4.07	244	28.48	18.49	18.37	2.00	1.00	0.00	1.00
2	4.11	246	28.44	18.48	18.36	2.00	1.00	0.00	1.00
2	4.14	248	28.40	18.48	18.36	2.00	1.00	0.00	1.00
2	4.18	250	28.36	18.47	18.35	2.00	1.00	0.00	1.00
2	4.21	252	28.33	18.47	18.34	2.00	1.00	0.00	1.00
2	4.24	254	28.29	18.46	18.34	2.00	1.00	0.00	1.00
2	4.28	256	28.26	18.45	18.33	2.00	1.00	0.00	1.00
2	4.31	258	28.22	18.45	18.33	2.00	1.00	0.00	1.00
2	4.34	260	28.19	18.44	18.32	2.00	1.00	0.00	1.00
2	4.38	262	28.15	18.44	18.32	2.00	1.00	0.00	1.00
2	4.41	264	28.12	18.43	18.31	2.00	1.00	0.00	1.00
2	4.44	266	28.08	18.43	18.31	2.00	1.00	0.00	1.00
2	4.48	268	28.05	18.42	18.30	2.00	1.00	0.00	1.00
2	4.51	270	28.02	18.42	18.30	2.00	1.00	0.00	1.00
2	4.54	272	27.98	18.41	18.29	2.00	1.00	0.00	1.00
2	4.58	274	27.95	18.41	18.29	2.00	1.00	0.00	1.00
2	4.61	276	27.92	18.40	18.28	2.00	1.00	0.00	1.00
2	4.64	278	27.89	18.40	18.28	2.00	1.00	0.00	1.00
2	4.68	280	27.86	18.39	18.28	2.00	1.00	0.00	1.00
2	4.71	282	27.82	18.39	18.27	2.00	1.00	0.00	1.00
2	4.74	284	27.79	18.38	18.27	2.00	1.00	0.00	1.00
2	4.78	286	27.76	18.38	18.26	2.00	1.00	0.00	1.00
2	4.81	288	27.73	18.37	18.26	2.00	1.00	0.00	1.00
2	4.84	290	27.70	18.37	18.25	2.00	1.00	0.00	1.00
2	4.88	292	27.67	18.36	18.25	2.00	1.00	0.00	1.00
2	4.91	294	27.64	18.36	18.24	2.00	1.00	0.00	1.00
2	4.94	296	27.61	18.35	18.24	2.00	1.00	0.00	1.00
2	4.98	298	27.59	18.35	18.24	2.00	1.00	0.00	1.00
2	5.01	300	27.56	18.34	18.23	2.00	1.00	0.00	1.00
2	5.04	302	27.53	18.34	18.23	2.00	1.00	0.00	1.00
2	5.08	304	27.50	18.34	18.22	2.00	1.00	0.00	1.00
2	5.11	306	27.47	18.33	18.22	2.00	1.00	0.00	1.00
2	5.14	308	27.45	18.33	18.22	2.00	1.00	0.00	1.00
2	5.18	310	27.42	18.32	18.21	2.00	1.00	0.00	1.00
2	5.21	312	27.39	18.32	18.21	2.00	1.00	0.00	1.00
2	5.24	314	27.37	18.31	18.20	2.00	1.00	0.00	1.00

2	5.28	316	27.34	18.31	18.20	2.00	1.00	0.00	1.00
2	5.31	318	27.31	18.31	18.20	2.00	1.00	0.00	1.00
2	5.34	320	27.29	18.30	18.19	2.00	1.00	0.00	1.00
2	5.38	322	27.26	18.30	18.19	2.00	1.00	0.00	1.00
2	5.41	324	27.24	18.29	18.19	2.00	1.00	0.00	1.00
2	5.44	326	27.21	18.29	18.18	2.00	1.00	0.00	1.00
2	5.48	328	27.19	18.29	18.18	2.00	1.00	0.00	1.00
2	5.51	330	27.17	18.28	18.18	2.00	1.00	0.00	1.00
2	5.54	332	27.14	18.28	18.17	2.00	1.00	0.00	1.00
2	5.58	334	27.12	18.28	18.17	2.00	1.00	0.00	1.00
2	5.61	336	27.09	18.27	18.16	2.00	1.00	0.00	1.00
2	5.64	338	27.07	18.27	18.16	2.00	1.00	0.00	1.00
2	5.68	340	27.05	18.26	18.16	2.00	1.00	0.00	1.00
2	5.71	342	27.02	18.26	18.15	2.00	1.00	0.00	1.00
2	5.74	344	27.00	18.26	18.15	2.00	1.00	0.00	1.00
2	5.78	346	26.98	18.25	18.15	2.00	1.00	0.00	1.00
2	5.81	348	26.96	18.25	18.15	2.00	1.00	0.00	1.00
2	5.85	350	26.94	18.25	18.14	2.00	1.00	0.00	1.00
2	5.88	352	26.91	18.24	18.14	2.00	1.00	0.00	1.00
2	5.91	354	26.89	18.24	18.14	2.00	1.00	0.00	1.00
2	5.95	356	26.87	18.24	18.13	2.00	1.00	0.00	1.00
2	5.98	358	26.85	18.23	18.13	2.00	1.00	0.00	1.00
2	6.01	360	26.83	18.23	18.13	2.00	1.00	0.00	1.00
2	6.05	362	26.81	18.23	18.12	2.00	1.00	0.00	1.00
2	6.08	364	26.79	18.22	18.12	2.00	1.00	0.00	1.00
2	6.11	366	26.77	18.22	18.12	2.00	1.00	0.00	1.00
2	6.15	368	26.75	18.22	18.11	2.00	1.00	0.00	1.00
2	6.18	370	26.73	18.21	18.11	2.00	1.00	0.00	1.00
2	6.21	372	26.71	18.21	18.11	2.00	1.00	0.00	1.00
2	6.25	374	26.69	18.21	18.11	2.00	1.00	0.00	1.00
2	6.28	376	26.67	18.21	18.10	2.00	1.00	0.00	1.00
2	6.31	378	26.65	18.20	18.10	2.00	1.00	0.00	1.00
2	6.35	380	26.63	18.20	18.10	2.00	1.00	0.00	1.00
2	6.38	382	26.62	18.20	18.10	2.00	1.00	0.00	1.00
2	6.41	384	26.60	18.19	18.09	2.00	1.00	0.00	1.00
2	6.45	386	26.58	18.19	18.09	2.00	1.00	0.00	1.00
2	6.48	388	26.56	18.19	18.09	2.00	1.00	0.00	1.00
2	6.51	390	26.54	18.19	18.08	2.00	1.00	0.00	1.00
2	6.55	392	26.53	18.18	18.08	2.00	1.00	0.00	1.00
2	6.58	394	26.51	18.18	18.08	2.00	1.00	0.00	1.00
2	6.61	396	26.49	18.18	18.08	2.00	1.00	0.00	1.00
2	6.65	398	26.48	18.17	18.07	2.00	1.00	0.00	1.00
2	6.68	400	26.46	18.17	18.07	2.00	1.00	0.00	1.00
2	6.71	402	26.44	18.17	18.07	2.00	1.00	0.00	1.00
2	6.75	404	26.43	18.17	18.07	2.00	1.00	0.00	1.00
2	6.78	406	26.41	18.16	18.06	2.00	1.00	0.00	1.00
2	6.81	408	26.39	18.16	18.06	2.00	1.00	0.00	1.00
2	6.85	410	26.38	18.16	18.06	2.00	1.00	0.00	1.00
2	6.88	412	26.36	18.16	18.06	2.00	1.00	0.00	1.00
2	6.91	414	26.35	18.15	18.06	2.00	1.00	0.00	1.00
2	6.95	416	26.33	18.15	18.05	2.00	1.00	0.00	1.00
2	6.98	418	26.31	18.15	18.05	2.00	1.00	0.00	1.00
2	7.01	420	26.30	18.15	18.05	2.00	1.00	0.00	1.00
2	7.05	422	26.28	18.14	18.05	2.00	1.00	0.00	1.00
2	7.08	424	26.27	18.14	18.04	2.00	1.00	0.00	1.00
2	7.11	426	26.26	18.14	18.04	2.00	1.00	0.00	1.00

2	7.15	428	26.24	18.14	18.04	2.00	1.00	0.00	1.00
2	7.18	430	26.23	18.14	18.04	2.00	1.00	0.00	1.00
2	7.21	432	26.21	18.13	18.04	2.00	1.00	0.00	1.00
2	7.25	434	26.20	18.13	18.03	2.00	1.00	0.00	1.00
2	7.28	436	26.18	18.13	18.03	2.00	1.00	0.00	1.00
2	7.31	438	26.17	18.13	18.03	2.00	1.00	0.00	1.00
2	7.35	440	26.16	18.12	18.03	2.00	1.00	0.00	1.00
2	7.38	442	26.14	18.12	18.03	2.00	1.00	0.00	1.00
2	7.41	444	26.13	18.12	18.02	2.00	1.00	0.00	1.00
2	7.45	446	26.12	18.12	18.02	2.00	1.00	0.00	1.00
2	7.48	448	26.10	18.12	18.02	2.00	1.00	0.00	1.00
2	7.52	450	26.09	18.11	18.02	2.00	1.00	0.00	1.00
2	7.55	452	26.08	18.11	18.02	2.00	1.00	0.00	1.00
2	7.58	454	26.07	18.11	18.01	2.00	1.00	0.00	1.00
2	7.62	456	26.05	18.11	18.01	2.00	1.00	0.00	1.00
2	7.65	458	26.04	18.11	18.01	2.00	1.00	0.00	1.00
2	7.68	460	26.03	18.10	18.01	2.00	1.00	0.00	1.00
2	7.72	462	26.02	18.10	18.01	2.00	1.00	0.00	1.00
2	7.75	464	26.00	18.10	18.01	2.00	1.00	0.00	1.00
2	7.78	466	25.99	18.10	18.00	2.00	1.00	0.00	1.00
2	7.82	468	25.98	18.10	18.00	2.00	1.00	0.00	1.00
2	7.85	470	25.97	18.09	18.00	2.00	1.00	0.00	1.00
2	7.88	472	25.96	18.09	18.00	2.00	1.00	0.00	1.00
2	7.92	474	25.95	18.09	18.00	2.00	1.00	0.00	1.00
2	7.95	476	25.93	18.09	18.00	2.00	1.00	0.00	1.00
2	7.98	478	25.92	18.09	17.99	2.00	1.00	0.00	1.00
2	8.02	480	25.91	18.09	17.99	2.00	1.00	0.00	1.00
2	8.05	482	25.90	18.08	17.99	2.00	1.00	0.00	1.00
2	8.08	484	25.89	18.08	17.99	2.00	1.00	0.00	1.00
2	8.12	486	25.88	18.08	17.99	2.00	1.00	0.00	1.00
2	8.15	488	25.87	18.08	17.99	2.00	1.00	0.00	1.00
2	8.18	490	25.86	18.08	17.98	2.00	1.00	0.00	1.00
2	8.22	492	25.85	18.08	17.98	2.00	1.00	0.00	1.00
2	8.25	494	25.84	18.07	17.98	2.00	1.00	0.00	1.00
2	8.28	496	25.83	18.07	17.98	2.00	1.00	0.00	1.00
2	8.32	498	25.82	18.07	17.98	2.00	1.00	0.00	1.00
2	8.35	500	25.81	18.07	17.98	2.00	1.00	0.00	1.00
2	8.38	502	25.80	18.07	17.98	2.00	1.00	0.00	1.00
2	8.42	504	25.79	18.07	17.97	2.00	1.00	0.00	1.00
2	8.45	506	25.78	18.06	17.97	2.00	1.00	0.00	1.00
2	8.48	508	25.77	18.06	17.97	2.00	1.00	0.00	1.00
2	8.52	510	25.76	18.06	17.97	2.00	1.00	0.00	1.00
2	8.55	512	25.75	18.06	17.97	2.00	1.00	0.00	1.00
2	8.58	514	25.74	18.06	17.97	2.00	1.00	0.00	1.00
2	8.62	516	25.73	18.06	17.97	2.00	1.00	0.00	1.00
2	8.65	518	25.72	18.06	17.96	2.00	1.00	0.00	1.00
2	8.68	520	25.71	18.05	17.96	2.00	1.00	0.00	1.00
2	8.72	522	25.71	18.05	17.96	2.00	1.00	0.00	1.00
2	8.75	524	25.70	18.05	17.96	2.00	1.00	0.00	1.00
2	8.78	526	25.69	18.05	17.96	2.00	1.00	0.00	1.00
2	8.82	528	25.68	18.05	17.96	2.00	1.00	0.00	1.00
2	8.85	530	25.67	18.05	17.96	2.00	1.00	0.00	1.00
2	8.88	532	25.66	18.05	17.96	2.00	1.00	0.00	1.00
2	8.92	534	25.65	18.05	17.95	2.00	1.00	0.00	1.00
2	8.95	536	25.65	18.04	17.95	2.00	1.00	0.00	1.00
2	8.98	538	25.64	18.04	17.95	2.00	1.00	0.00	1.00

2	9.02	540	25.63	18.04	17.95	2.00	1.00	0.00	1.00
2	9.05	542	25.62	18.04	17.95	2.00	1.00	0.00	1.00
2	9.08	544	25.61	18.04	17.95	2.00	1.00	0.00	1.00
2	9.12	546	25.61	18.04	17.95	2.00	1.00	0.00	1.00
2	9.15	548	25.60	18.04	17.95	2.00	1.00	0.00	1.00

Press any key to continue

Modified Shivering function to reduce shiver oscillations

```
/*
  Name: Larry Berglund
        Date: 7/03/02
        File: Dani_Verif_Air_Water_Wet2nm02.c

        This simulates the thermal response of a person moving through a series
        of 3 constant environments: air, water, air with wetskin and or clothing.
        Shivering functions If statement modified to reduce shiver oscillation.
*/

#include <assert.h>
#include <stdio.h>
#include <math.h>
#include <ctype.h>

#define TTSK 33.7
#define TTCR 36.8
#define TTBM 36.49   /*TTBM=.9*TTCR+.1*TTSK =36.49 */
#define BAR 760.
#define CSW 170.
#define CDIL 50. /* CDIL 200 super athlete, 50 average person */
#define CSTR .5
#define SKBFN 6.3
#define Skbfmax 90.
#define Skbfmin 2.
#define CMIN 5.28
#define CB 1.163
#define DT 0.0167   /* Time step 1/60=.0167 hr */

double SatVapPres(double T);
double Convection(double Xmet, double V);
double Respiration(double Xmet, double Ta, double Pa);
double Shiver(double Tc, double Tsk);
double SkinBloodFlow(double Tc, double Tsk);
double Alpha(double Skbf);
double Sweat(double Tc, double Tsk,double alpha);
void OutputHeader();
double Core(double Tc,double Tsk,double Xmet,double Res,double* hfcsk, double skbf,double* RmNet);
double Skin(double wet,double Dry,double Emax,double* hfcsk);
double Skin_wet_cl(double wet,double Rbound,double Emax,double* hfcsk,double Tcl,double To);

int main (void)
{
        int Envir,steps,step;
        double Ta,Tr,Tdp,RH,Pa,Psk,Pscl,Tcl,To,ET,ETR,Tw, V,hc,Hc,he,He,hr;
        double
wet,Tsk,Tskn,Tc,Tbm,Xmet,We,XmetNet,RmNet,metA,metW,metR,clo,FCL,FACL,Dry,Fpcl;
        double Emax,Esk,Eskin,Edif,Res,EresDryRes,Skbf,alpha,Regsw,Ersw,heatFlowCoreToSkin;
        double
HSCR,HSSK,TCCR,TCSK,Rcl,Rclw,Rbound,Rpcl,Rpbound,time,TIM,durationA,durationW,durationR;
        TIM=0;
        step=0;
        time =0;
        printf("Enter conditions: clo Ta(C) Tr Tdp V(km/h) Tw  ");
```

```
	scanf("%lf%lf%lf%lf%lf%lf",&clo,&Ta,&Tr,&Tdp,&V,&Tw);
	V =V*1000/(60*60); /* convert km/h to m/s */
	printf("V=%6.2f m/s\n",V);
	printf("Enter initial physiology (or 0's if neutral or unknown): wet Tsk Tc ");/* inserts
		default  values if wet,Tsk,Tcr are zero's */
	scanf("%lf%lf%lf",&wet,&Tsk,&Tc);
	printf("Enter exposure durations(h): air water raft steps(min) ");
      /* time is duration in hours, steps is min. between print interval*/
	scanf("%lf%lf%lf%d",&durationA,&durationW,&durationR,&steps);
	time+=durationA;
	if (wet <=0)
		wet=.06;
	if (Tsk <=0)
		Tsk=33;
	if (Tc <=0)
		Tc=36.9;
	printf("Enter exposure met level: air water raft  ");
      /* met is relative acivity, resting met=1, walking=3 */
	scanf("%lf%lf%lf",&metA,&metW,&metR);
	OutputHeader();
We=0;
	Xmet=metA;
	XmetNet=(1-We)*Xmet;
	RmNet=58.2*XmetNet; /* watts/(m^2) */

	Pa=SatVapPres(Tdp); /* vapor press Torr */
	RH=Pa/(SatVapPres(Ta));
	Hc = Convection(Xmet,V); /* convection */
	He=2.2*Hc;  /* evaporation   watts/(m^2 Torr) */
	hr=4.5; /*radiation watts/(m^2 K) */
	To=(hc*Ta + hr*Tr)/(hc+hr);
	FACL=1.0+.2*clo; /* surface area of clothing relative to Adu */
	Rcl=.155*clo; /* clothing thermal resistance m^2 C/watts */
	Rbound=1/((hr+hc)*FACL); /*  boundary layer thermal resistance m^2 C/watts */
	Dry=(Tsk-To)/(Rcl+Rbound);

	for(Envir=0;Envir<=2;Envir++)
	{
	if (Envir==1)
		time+=durationW;
	if (Envir==2)
		time+=durationR;

	while (TIM<time)  /* thermo-physiology loop */
	{
		/* dry and evaporative heat transfer*/
		if (Envir==1)
		{
			Xmet=metW;
			XmetNet=(1-We)*Xmet;
			hc=230;
			hr=0;
			Rclw=Rcl/70;
			To=Tw;
			wet=1;
			Rbound=1/((hc+hr)*FACL);
```

```
		Dry=(Tsk-To)/(Rclw+Rbound);
		Tcl=(To*Rclw + Tsk*Rbound)/(Rclw+Rbound);/* steady state analysis */
	}
	else
	{
		Rpcl= .153181*clo;
		Psk=SatVapPres(Tsk); /* vapor press Torr */

		if(Envir==0)
			{
			Xmet=metA;
			XmetNet=(1-We)*Xmet;
			hc=Hc;
			Tcl = To +Dry/(FACL*(hr+hc));
			he=He;
			Rpbound=1/(he*FACL);
			Emax=(Psk-Pa)/(Rpcl+Rpbound);
			Fpcl=1/(1+.153181*he*FACL*clo); /*Berglund 1981, for IL=.45*/
			}
		if (Envir==2)
			{
			Xmet=metR;
			XmetNet=(1-We)*Xmet;
			hc= Convection(Xmet,V); /* convection */
			he=2.2*hc;  /* evaporation   watts/(m^2 Torr) */
			Rpbound=1/(he*FACL);
			}

		hr=4*.725*(5.67E-08)*pow(((Tcl+To)/2+273),3); /* corrected hr */
		To=(hc*Ta + hr*Tr)/(hc+hr);
		Rbound=1/((hc+hr)*FACL);
		Dry=(Tsk-To)/(Rcl+Rbound); /* only used for Envir=0 */
	}

	/* Thermal Physiology */
	Res = Respiration(Xmet,Ta,Pa);

	Skbf=SkinBloodFlow(Tc,Tsk); /* Liters/(h m^2) */
	alpha=Alpha(Skbf);
	Regsw=Sweat(Tc,Tsk,alpha); /*g/(h m^2) */
	if (Envir==1)
		{
		Emax=0;
		}
	else
		{
		if (Envir==2)
			{
			Pscl=SatVapPres(Tcl);
			Emax=he*FACL*(Pscl-Pa);
			wet=1;
			Tcl=(Tsk*Rbound+To*Rclw-wet*Emax*Rclw*Rbound)/(Rclw+Rbound);
/*steady state, wet clothing	*/
			}
		else  /* Envir=0 */
			{
```

```
                        Ersw=.68*Regsw;  /* watts/m^2 */
                        wet=Regsw/Emax;
                        if (wet>=1)
                                wet=1;
                        Esk=(.06+.94*wet)*Emax;
                        Edif = (1-wet)*.06*Emax;
                        }
                }
        HSCR = Core(Tc,Tsk,XmetNet,Res,&heatFlowCoreToSkin,Skbf,&RmNet);
        if(Envir==2)
                HSSK = Skin_wet_cl(wet,Rbound,Emax,&heatFlowCoreToSkin,Tcl,To);
        else
                HSSK = Skin(wet,Dry,Emax,&heatFlowCoreToSkin);

        if (step%steps==0)
        printf(" %5d %11.2f %6d %6.2f %6.2f %6.2f %6.2f %6.2f %6.2f %9.2f
\n",Envir,TIM,step,Tc,Tsk,Tcl,Skbf,RmNet/58.2,
                        Regsw/60,wet);

        /* thermal capacity */
        TCCR=.97*(1-alpha)*70;
        TCSK=.97*alpha*70;
        /* stepwise integration */
        Tc +=HSCR*1.8/TTCR*DT;
        Tsk +=HSSK*1.8/TTSK*DT;
        TIM +=DT;
        step +=1;
        }
    }
    return 0;
}

void OutputHeader()
{
    printf("\nEnvironment time(h)   min.  Tc    Tsk   Tcl    Skbf   metNet sw g/m^2min wet\n");
}

double SatVapPres(double T)
{
    double Pst;
        Pst = exp(18.6686-(4030.183/(T+235.)));
    return Pst;
}

double Convection(double Xmet,double V)
{
    double CHCA, CHCV, CHCmin, hc;
    CHCmin = 3.0;
    CHCA = 5.66*pow((Xmet - 0.85),0.39); /* hc due to activity */
    CHCV = 8.6*pow(V,0.53);             /* hc due to air speed V in m/s */
        if (CHCV >= CHCmin)
                ;
        else
                (CHCV = CHCmin);
        if (CHCV >= CHCA)
                hc = CHCV;
```

```
		else
			hc = CHCA;
	return hc;
}

double Respiration(double Xmet, double Ta, double Pa)
{
	double RM,Res,Eres,Cres;
	RM = 58.2*Xmet;
	Eres = 0.0023*RM*(44.-Pa);  /* watts/m2 */
	Cres = 0.0014*RM*(34.-Ta);  /* watts/m2 */
	Res = Eres + Cres;
	return Res;
}

double Shiver(double Tc, double Tsk) /* Tikusis & Stolwijk Models */
{
	double shiver,BF;
	shiver=0; BF=15; /* BF is % body fat */
	if (Tc<37 || Tsk<33)		/* does shiving occur/*/
	{	if (Tc<37 && Tsk<33)		/*shiver diven by core and skin*/
			shiver=(156*(37-Tc)+47*(33-Tsk)-1.57*pow((33-Tsk),2))/pow(BF,0.5);/*Tikusis
and
							Giesbrecht,1999,15%BF*/
		else
			if(Tc<37)  /*shiver driven core only*/
				shiver=(156*(37-Tc))/pow(BF,0.5);
			else
				shiver=(47*(33-Tsk)-1.57*pow((33-Tsk),2))/pow(BF,0.5);
	}

/*	if (Tc<TTCR && Tsk<TTSK)	/* Stolwijk */
/*		shiver = 19.4*(Tc-TTCR)*(Tsk-TTSK);*/
/*	shiver=0;  */	/*Use to disable shiver*/
  return shiver;
}

double SkinBloodFlow(double Tc, double Tsk)
{
	double Colds=0;
	double Skbf, WarmC=0;
	if (Tsk<TTSK)
		Colds=TTSK-Tsk;
	if (Tc>TTCR)
		WarmC=Tc-TTCR;
	Skbf=(SKBFN+CDIL*WarmC)/(1+CSTR*Colds);
	if (Skbf>Skbfmax)
		Skbf= Skbfmax;
	if (Skbf<Skbfmin)
		Skbf= Skbfmin;
	return Skbf;
}

double Alpha(double Skbf)
{
	double alpha;
```

```
        alpha=0.04177+.74518/(Skbf+0.585417);
        return alpha;
}

double Sweat(double Tc, double Tsk, double alpha)
{
        double regsw, Tmb;
        regsw=0;
        Tmb=(1-alpha)*Tc + alpha*Tsk;
                if ((Tmb>TTBM)&&(Tsk>TTSK))
                        regsw=CSW*(Tmb-TTBM)*exp((Tsk-TTSK)/10.7);
                else if ((Tmb>TTBM)&&(Tsk<=TTSK))
                        regsw=CSW*(Tmb-TTBM);
        if (regsw>667)
                regsw=667;  /* regsw_max=667g/(h m^2)=11.1g/(min m^2)!=20g/(min m^2) */
        return regsw;
}

double Core(double Tc,double Tsk,double XmetNet,double Res,double*heatFlowCoreToSkin, double
Skbf, double*RmNet)
{
        double RmetNet,Hfcrsk,HSCR,shiver;
   shiver=Shiver(Tc,Tsk);          /* watts/m^2 */
        Hfcrsk=(CMIN+CB*Skbf)*(Tc-Tsk);   /* watts/m^2 */
        RmetNet = 58.2*XmetNet + shiver;    /* metabolic heat produced watts/m^2 */
        HSCR=RmetNet-Hfcrsk-Res;            /* rate of heat storage in core  watts/m^2 */
        *heatFlowCoreToSkin=Hfcrsk;
        *RmNet=RmetNet;
        return HSCR;
}

double Skin(double wet,double Dry,double Emax,double*heatFlowCoreToSkin )
{
        double Esw,Ediff,Esk,HSSK;
        Esw=wet*Emax;
        Ediff=.06*(1-wet)*Emax;
        Esk=Esw+Ediff;
        HSSK=*heatFlowCoreToSkin-Dry-Esk; /* rate of heat storage in skin watts/m^2 */
        return HSSK;
}

double Skin_wet_cl(double wet,double Rbound,double Emax,double*heatFlowCoreToSkin,double
Tcl,double To)
{
        double Escl,Dry,HSSK;
        Escl=wet*Emax;  /*evaporation from clothing*/
        Dry=(Tcl-To)/Rbound;
        HSSK=*heatFlowCoreToSkin-Dry-Escl;  /*at steady state heat flow from skin = heat flow from
clothing */
        return HSSK;
}

/* This is the End */

/* output is pasted below
report data
```

Enter conditions: clo Ta(C) Tr Tdp V(km/h) Tw .7 20.6 20.6 14 7.4 17
V= 2.06 m/s
Enter initial physiology (or 0's if neutral or unknown): wet Tsk Tc 0 0 0
Enter exposure durations(h): air water raft steps(min) 0 .1666 9 2
Enter exposure met level: air water raft 1 3 1

Envir	time(h)	min.	Tc	Tsk	Tcl	Skbf	metNet	sw g/m^2min	wet
1	0.00	0	36.90	33.00	28.38	8.37	3.07	0.00	1.00
1	0.03	2	37.07	28.24	24.99	5.35	3.84	0.00	1.00
1	0.07	4	37.24	24.99	22.68	5.29	4.22	0.00	1.00
1	0.10	6	37.38	22.80	21.12	5.46	4.40	0.00	1.00
1	0.13	8	37.49	21.32	20.07	5.65	4.49	0.00	1.00
2	0.17	10	37.57	20.32	20.08	5.81	2.52	0.00	1.00
2	0.20	12	37.47	20.40	20.13	5.18	2.52	0.00	1.00
2	0.23	14	37.39	20.43	20.16	4.67	2.52	0.00	1.00
2	0.27	16	37.32	20.44	20.17	4.27	2.52	0.00	1.00
2	0.30	18	37.28	20.44	20.17	3.95	2.52	0.00	1.00
2	0.33	20	37.24	20.42	20.16	3.69	2.52	0.00	1.00
2	0.37	22	37.21	20.40	20.14	3.49	2.52	0.00	1.00
2	0.40	24	37.18	20.37	20.11	3.32	2.52	0.00	1.00
2	0.43	26	37.16	20.34	20.08	3.19	2.52	0.00	1.00
2	0.47	28	37.15	20.31	20.05	3.09	2.52	0.00	1.00
2	0.50	30	37.14	20.28	20.02	3.00	2.53	0.00	1.00
2	0.53	32	37.13	20.25	19.99	2.93	2.53	0.00	1.00
2	0.57	34	37.12	20.22	19.97	2.88	2.53	0.00	1.00
2	0.60	36	37.11	20.19	19.94	2.83	2.53	0.00	1.00
2	0.63	38	37.11	20.16	19.91	2.79	2.53	0.00	1.00
2	0.67	40	37.10	20.13	19.89	2.76	2.53	0.00	1.00
2	0.70	42	37.10	20.11	19.86	2.73	2.53	0.00	1.00
2	0.73	44	37.10	20.08	19.84	2.71	2.53	0.00	1.00
2	0.77	46	37.09	20.06	19.82	2.69	2.53	0.00	1.00
2	0.80	48	37.09	20.04	19.80	2.68	2.53	0.00	1.00
2	0.84	50	37.09	20.02	19.79	2.66	2.53	0.00	1.00
2	0.87	52	37.09	20.01	19.77	2.65	2.53	0.00	1.00
2	0.90	54	37.09	19.99	19.76	2.64	2.53	0.00	1.00
2	0.94	56	37.09	19.98	19.74	2.63	2.53	0.00	1.00
2	0.97	58	37.09	19.96	19.73	2.62	2.53	0.00	1.00
2	1.00	60	37.09	19.95	19.72	2.61	2.53	0.00	1.00
2	1.04	62	37.09	19.94	19.71	2.61	2.54	0.00	1.00
2	1.07	64	37.08	19.93	19.70	2.60	2.54	0.00	1.00
2	1.10	66	37.08	19.92	19.69	2.60	2.54	0.00	1.00
2	1.14	68	37.08	19.91	19.68	2.59	2.54	0.00	1.00
2	1.17	70	37.08	19.90	19.67	2.59	2.54	0.00	1.00
2	1.20	72	37.08	19.89	19.67	2.59	2.54	0.00	1.00
2	1.24	74	37.08	19.89	19.66	2.58	2.54	0.00	1.00
2	1.27	76	37.08	19.88	19.65	2.58	2.54	0.00	1.00
2	1.30	78	37.08	19.87	19.65	2.58	2.54	0.00	1.00
2	1.34	80	37.08	19.87	19.64	2.57	2.54	0.00	1.00
2	1.37	82	37.08	19.86	19.64	2.57	2.54	0.00	1.00
2	1.40	84	37.08	19.86	19.64	2.57	2.54	0.00	1.00
2	1.44	86	37.08	19.86	19.63	2.57	2.54	0.00	1.00
2	1.47	88	37.08	19.85	19.63	2.57	2.54	0.00	1.00
2	1.50	90	37.08	19.85	19.63	2.57	2.54	0.00	1.00
2	1.54	92	37.08	19.85	19.62	2.56	2.54	0.00	1.00
2	1.57	94	37.08	19.84	19.62	2.56	2.54	0.00	1.00

2	1.60	96	37.08	19.84	19.62	2.56	2.54	0.00	1.00
2	1.64	98	37.08	19.84	19.62	2.56	2.54	0.00	1.00
2	1.67	100	37.08	19.84	19.61	2.56	2.54	0.00	1.00
2	1.70	102	37.08	19.83	19.61	2.56	2.54	0.00	1.00
2	1.74	104	37.08	19.83	19.61	2.56	2.54	0.00	1.00
2	1.77	106	37.08	19.83	19.61	2.56	2.54	0.00	1.00
2	1.80	108	37.08	19.83	19.61	2.56	2.54	0.00	1.00
2	1.84	110	37.08	19.83	19.61	2.56	2.54	0.00	1.00
2	1.87	112	37.08	19.83	19.60	2.56	2.54	0.00	1.00
2	1.90	114	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	1.94	116	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	1.97	118	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	2.00	120	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	2.04	122	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	2.07	124	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	2.10	126	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	2.14	128	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	2.17	130	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	2.20	132	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	2.24	134	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	2.27	136	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	2.30	138	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	2.34	140	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	2.37	142	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	2.40	144	37.08	19.82	19.60	2.55	2.54	0.00	1.00
2	2.44	146	37.08	19.82	19.59	2.55	2.54	0.00	1.00
2	2.47	148	37.08	19.82	19.59	2.55	2.54	0.00	1.00
2	2.51	150	37.08	19.82	19.59	2.55	2.54	0.00	1.00
2	2.54	152	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	2.57	154	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	2.61	156	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	2.64	158	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	2.67	160	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	2.71	162	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	2.74	164	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	2.77	166	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	2.81	168	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	2.84	170	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	2.87	172	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	2.91	174	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	2.94	176	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	2.97	178	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.01	180	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.04	182	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.07	184	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.11	186	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.14	188	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.17	190	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.21	192	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.24	194	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.27	196	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.31	198	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.34	200	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.37	202	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.41	204	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.44	206	37.08	19.81	19.59	2.55	2.54	0.00	1.00

2	3.47	208	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.51	210	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.54	212	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.57	214	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.61	216	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.64	218	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.67	220	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.71	222	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.74	224	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.77	226	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.81	228	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.84	230	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.87	232	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.91	234	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.94	236	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	3.97	238	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.01	240	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.04	242	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.07	244	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.11	246	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.14	248	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.18	250	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.21	252	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.24	254	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.28	256	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.31	258	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.34	260	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.38	262	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.41	264	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.44	266	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.48	268	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.51	270	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.54	272	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.58	274	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.61	276	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.64	278	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.68	280	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.71	282	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.74	284	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.78	286	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.81	288	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.84	290	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.88	292	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.91	294	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.94	296	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	4.98	298	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.01	300	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.04	302	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.08	304	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.11	306	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.14	308	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.18	310	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.21	312	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.24	314	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.28	316	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.31	318	37.08	19.81	19.59	2.55	2.54	0.00	1.00

2	5.34	320	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.38	322	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.41	324	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.44	326	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.48	328	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.51	330	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.54	332	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.58	334	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.61	336	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.64	338	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.68	340	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.71	342	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.74	344	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.78	346	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.81	348	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.85	350	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.88	352	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.91	354	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.95	356	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	5.98	358	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.01	360	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.05	362	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.08	364	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.11	366	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.15	368	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.18	370	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.21	372	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.25	374	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.28	376	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.31	378	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.35	380	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.38	382	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.41	384	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.45	386	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.48	388	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.51	390	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.55	392	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.58	394	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.61	396	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.65	398	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.68	400	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.71	402	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.75	404	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.78	406	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.81	408	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.85	410	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.88	412	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.91	414	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.95	416	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	6.98	418	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.01	420	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.05	422	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.08	424	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.11	426	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.15	428	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.18	430	37.08	19.81	19.59	2.55	2.54	0.00	1.00

2	7.21	432	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.25	434	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.28	436	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.31	438	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.35	440	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.38	442	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.41	444	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.45	446	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.48	448	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.52	450	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.55	452	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.58	454	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.62	456	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.65	458	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.68	460	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.72	462	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.75	464	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.78	466	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.82	468	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.85	470	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.88	472	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.92	474	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.95	476	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	7.98	478	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.02	480	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.05	482	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.08	484	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.12	486	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.15	488	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.18	490	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.22	492	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.25	494	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.28	496	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.32	498	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.35	500	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.38	502	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.42	504	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.45	506	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.48	508	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.52	510	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.55	512	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.58	514	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.62	516	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.65	518	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.68	520	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.72	522	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.75	524	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.78	526	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.82	528	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.85	530	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.88	532	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.92	534	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.95	536	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	8.98	538	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	9.02	540	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	9.05	542	37.08	19.81	19.59	2.55	2.54	0.00	1.00

2	9.08	544	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	9.12	546	37.08	19.81	19.59	2.55	2.54	0.00	1.00
2	9.15	548	37.08	19.81	19.59	2.55	2.54	0.00	1.00

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